# ADVANCED PHYSIOLOGY AND HYGIENE

CONN
AND
BUDINGTON

SILVER, BURDETT & COMPANY

John Forbes Rickard.

# ADVANCED PHYSIOLOGY AND HYGIENE

*FOR USE IN SECONDARY SCHOOLS*

BY

HERBERT W. CONN, Ph.D.,

FORMERLY PROFESSOR OF BIOLOGY IN WESLEYAN UNIVERSITY

AND

ROBERT A. BUDINGTON, A.M.,

PROFESSOR OF ZOOLOGY IN OBERLIN COLLEGE

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## THE CONN SERIES OF PHYSIOLOGIES

By H. W. Conn, Ph.D.

*Formerly Professor of Biology, Wesleyan University*

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# PREFACE

When the science of physiology was first introduced into schools the texts offered for study treated largely of anatomy. As the subject developed and expanded it was recognized that the study of anatomy should be made subordinate to that of function, and the text-books came to give to function a place predominant over structure. Further experience emphasized the fact that the primary utility of the study of physiology in schools consists in its bearing upon health, and matters of personal hygiene came to occupy a more and more prominent place. Still more recently problems of public hygiene and general health have forced themselves to the front, and have been demonstrated to be an important part of a person's education. With this broadening scope and all these new aspects of life and health to be considered, many phases of the subject of physiology proper, themselves of scientific interest and importance, have inevitably been given less and less attention, while the more practical topics have been accorded fitting precedence.

Although perhaps no two teachers would agree as to the relative importance of any specific topic, certain it is, however, that without some knowledge of anatomy, physiological facts seem isolated and without foundation; while rules bearing on hygiene, taken alone, are learned by the student merely as barren rules without any persuasive reason for them. In this book the emphasis placed upon different subjects is that which has seemed to the writers to be a close approximation to their relative importance in the present state of the sciences of physiology and hygiene.

This book has one new feature which the authors feel

confident will commend it to physicians, health officers and public spirited citizens generally. In connection with the different systems of organs, the nature and causes of common diseases are discussed in simple terms with such suggestions about the prevention of disease as may help to make the high school student more intelligent in regard to his own health and the health of the community.

In the treatment of the problems of the physiological effects of alcohol it is assumed that students using this book are of an age to appreciate that some of the many problems connected with the use of this drug are still unsettled. Hence, while some aspects of this subject have been introduced without anticipating any final conclusion, the attempt is made to point out the most important of the evil effects resulting from the use of this drug.

The revised edition contains numerous additions to the text embodying the results of the most recent scientific investigations. Especial attention has been given the newer conceptions of proteid digestion, carbon dioxid in respiration, vitamines, the role of certain hormones, and the etiology of numerous diseases. Since the last few years have offered more convincing proof than ever before of the vital relation between hygiene and health, sanitation and safety, especial care has been taken to rewrite and to expand the chapter on public control of health. The number of laboratory exercises and demonstrations has been materially increased. These have been assembled in a separate section and placed in the back of the book with page reference to the portion of text to which each applies.

ROBERT A. BUDINGTON.

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# PHYSIOLOGY AND HEALTH

## CHAPTER I

### THE LIVING MATERIAL OF THE BODY

"Know thyself" was a motto of the ancient Greeks. Wise as such advice was in their day, it is far more necessary in these modern times of complex civilization. The Greeks knew less than we of the activities of the body organs, but they needed such knowledge less because their mode of living was simpler. Their lives were passed largely out of doors, never in close houses; their food was plain, but nourishing and abundant; their bodies were vigorous and active because they exercised all their muscles.

But to-day people are so crowded into cities that there is little time or opportunity for physical exercise and there is every facility for the distribution of contagious diseases. We shut ourselves up in close houses, thus depriving ourselves of needed air; we use trolleys, carriages, automobiles, telephones and mails to save the time and trouble of walking, we eat an endless variety of good and bad foods, variously prepared and often adulterated; we live in the midst of more or less constant and intense activity. Brain work takes the place of muscle work with part of the race while another part uses the brain very little.

Amid all these complexities the problem of retaining health and vigor is increasingly difficult. In our crowded cities people are living under unnatural conditions, and serious

questions are constantly arising as to the proper means for preserving health. Even country life is ceasing to be the simple, natural life that it was once, and the smaller communities are facing many of the problems of the large cities. With each succeeding year we realize more fully the need of understanding the laws of life in order to maintain both individual and public health. All this makes a constantly increasing demand for the study of those subjects which teach us how to keep our bodies and minds in a state of highest efficiency; and the study of physiology and hygiene has come to be recognized as one of the necessities of education.

**Normal and Experimental Physiology.—Physiology** is *the science of the activities of living things.* It may refer to the activities of animals or plants, of the whole animal or its parts, of the whole plant or its parts, or even of whole groups of animals or plants. If observations are made upon animals under healthy, normal conditions, while they are acting under their own ordinary impulses, the study is called **normal physiology.** Sometimes, however, an animal or a plant or parts of either may purposely be put under unnatural conditions and the result noted. We may change the food supply, the temperature or moisture of the substance in which it lives, we may try the effects upon it of drugs and poisons, or we may artificially stimulate it to action. In these cases the study is termed **experimental physiology.**

The term **physiology,** as commonly understood, refers to the study of the activities or functions of the different parts of the human body under normal conditions. Although thus primarily a study of activities, some attention must also be paid to structure; for if one is to understand thoroughly the working of any machine, he must know the form and position of its parts. The study of the structure of the body is called **anatomy.** Anatomy and physiology

are thus distinct subjects, yet so closely related that they will be considered separately.

## ORGANS AND TISSUES

There are several familiar fundamental facts concerning living things; everyone knows that the commoner animals feed, breathe, feel, give off waste material, have blood circulating through their bodies and show many other points of similarity. It may, however, surprise some people to learn that these same functions are carried on in plants, for they, too, must feed, breathe, give off waste and have some kind of circulatory system, although, to be sure, these life processes occur differently in animals and plants. An **organism** is *anything which carries out the functions of life.*

FIG. 1.—HYALODISCUS LIMAX
A microscopic animal resembling amœba, which lives in fresh water. All parts of the body are nearly alike and perform the same functions. *N* is the nucleus.

Certain very important differences exist between the lower (i.e. microscopic) organisms and the higher ones. In many of the lower types of animal and plant life all parts of the body may perform the same office, e. g. of locomotion, sensation or feeding; but it is apparent to anyone that different parts of the human body — such as heart, stomach, brain or eye, perform each its own work or function; and each is therefore called an organ. An **organ** may be defined as *a part of the body which has one special kind of work to do.* This work as a rule contributes to the sustaining of every other part of the organism. The whole body, then, may be pictured as composed of many separate and distinct organs, each coöperating with the other and thus constituting one organism. Even the microscopic animals, like those in Figure 1, have some very simple organs, as for instance, the nucleus shown at *N*.

This study of the parts of live organisms may be carried still further; and just as the stairway, or the elevator, or the windows of a house are not made entirely of wood, or of iron, or of glass, so also the human body is not composed throughout of the same kind of material. The nose, for example, is covered with skin; is lined with a smooth, moist membrane; contains a supporting framework, partly of soft cartilage, partly of bone; blood vessels are present in it; nerves make it sensitive to odors and to touch; hairs are provided for straining the air as one breathes; muscles permit slight movements. Such parts as these composing an organ are commonly called tissues. A **tissue** is *a single kind of living material with the power of doing a single kind of work.* Generally, several different kinds of tissue occur in the structure of a single organ. The hand, for example, contains bone tissue, muscle tissue, nerve tissue and blood tissue, besides several other kinds.

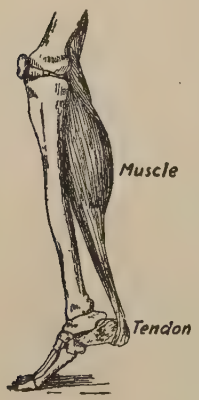



FIG. 2.—THE LEG
Showing the bones, muscles and tendons concerned in lifting the body upon the toes.

**Kinds of Tissues.**—The following are the most important tissues of the human body.

**Epithelium,** or covering tissue, is a thin layer covering the outer and inner surfaces of the body and of the different organs; e. g. the outer layers of the skin and the lining of the mouth and throat.

**Supporting tissues** include bone, cartilage and connective tissues. *Bone* forms the skeleton. *Cartilage* is found in many different regions of the body. It is placed between each two pieces of the 'back-bone'; it composes the principal part of the voice-box; it makes the ears and the nose somewhat rigid; it covers the ends of bones where they come together at moving

joints. Sometimes it connects the bones, e. g. as it joins the front ends of the ribs to the breast bones. *Connective tissue* occurs throughout the whole body, binding together the different parts. A simple kind of connective tissue is seen in beefsteak, where it appears in fine lines or as thin, glistening sheets holding together the small cord-like pieces of muscle tissue. More evident kinds of connective tissue are the ligaments and tendons; Fig. 2. Ligaments hold bones together at joints, as at the knee or the shoulder. Tendons connect muscles to bones, and may plainly be felt at the wrist where they pass from the muscles in the forearm to the bones in the fingers; Fig. 137. It is said that if all the other materials of the body were dissolved away and the connective tissue left, this tissue is so abundant that the form of the body would be perfectly retained.

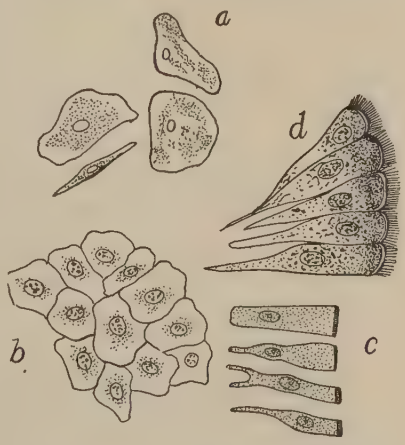



FIG. 3.—EPITHELIAL CELLS

*a*, flat, scale-like cells from the mouth; *b*, from the membranes around the intestine; *c*, from the intestine; *d*, ciliated epithelial cells from the wind pipe.

**Muscle tissue** forms the flesh and moves the different parts of the body.

**Gland tissue** composes organs and surfaces which generally produce some fluid secretion, like the saliva in the mouth, the tears in the eyes or the bile in the liver.

**Blood** forms the so-called "circulating tissue."

**Nerve tissue** is the material of which the brain and other parts of the nervous system are composed.

**Fat tissue,** while not active, serves to store material for future use.

A study of the organs and tissues of an organism as seen with unaided eye is called a study of its *macroscopic anatomy*. If a microscope is used, one is said to be studying its *microscopic anatomy*.

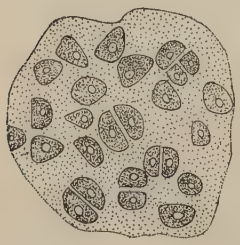


FIG. 4.—CARTILAGE CELLS
Embedded in an abundant intercellular matrix.

### MICROSCOPIC ANATOMY

After the invention of the microscope by two Dutchmen, Hans and Zacharias Janssen, about the year 1600, curiosity gradually led to the examination of all kinds of animal and plant substances under high magnification. Of special interest to us here is a fact established in 1838-1839, that all tissues in plants and animals are made up of definitely formed parts or units, somewhat in the manner in which the walls of brick buildings are made up of separate bricks.

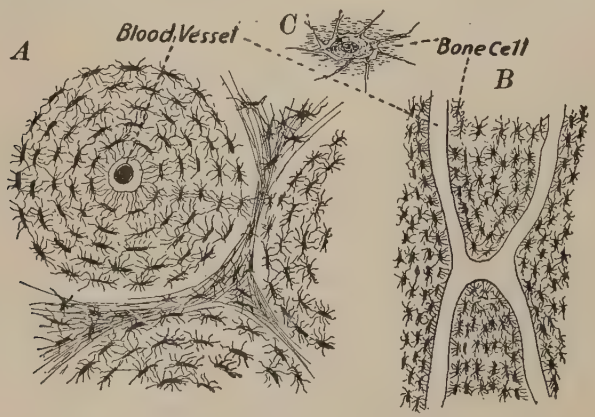



FIG. 5.—THE MICROSCOPIC STRUCTURE OF BONE
*A*, cross section; *B*, longitudinal section; *C*, a single young bone cell.

These small units had been seen two hundred years earlier and at that time were called **cells**, since it was thought that they were practically empty pockets. But to Schleiden and Schwann, who first demonstrated that all tissues are made up of such

cells, is given the main credit of firmly establishing what has since been known as the *cell theory of tissue structure*.

According to some students of the subject, these cells are connected, each with its neighboring cells, by very tiny, hollow tubes ("bridges"); but others are equally certain that each cell acts by itself, save as fluids may pass out from each cell and be carried to other cells of the body in the blood stream.

FIG. 6.—CONNECTIVE TISSUE
A bit of tendon highly magnified. At *C* are shown some of the cells which produced the fibres.

**Kinds of Cells.**—The shape of these cells is different in different kinds of tissues, just as bricks used in the foundations of buildings differ from those employed for fireplaces or ornamental work.

**Epithelial cells** are thin and disc-like or cylindrical in shape (Fig. 3 *a*, *b*, *c* and *d*) and usually have very little space between them.

**Cartilage cells** are round or hemispherical and are usually more widely separated; Fig. 4. The material between them, *intercellular substance*, has been formed by the cells themselves and secreted in large quantities, separating them as mortar does bricks.

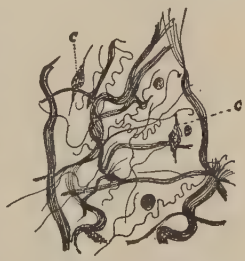



FIG. 7.—CONNECTIVE TISSUE
The soft tissue that lies between the skin and the muscles. Fibres are shown running irregularly, and some cells, *C*.

**Bone cells** are close together in very young bone, but later are separated by a secretion which they deposit around themselves. This deposit contains a mineral matter, *calcium phosphate*, which causes the mass to harden. As the bone develops, this hard mineral matter between the cells becomes very abundant, and finally, in the fully formed bone, the cells proper occupy very small spaces; Fig. 5.

**Connective tissue** shows almost no cells for it consists for the most part of numerous fine fibres, frequently arranged

in bundles, as in tendons (Fig. 6); or in confused masses running in all directions, as in the soft mass of connective tissue beneath the skin; Fig. 7. But in each a few genuine cells can be seen, and a study of the growth of connective tissue shows that the fibres are really produced by the cells.

FIG. 8.—MUSCLE CELLS FROM THE WALL OF THE INTESTINE

**Muscle tissue** consists of fibres, sometimes tapering at the ends; Fig. 8. When the muscle contracts, these fibres diminish in length and thicken in the middle. Such a fibre is sometimes a single muscle cell, and sometimes several cells fused together, but in any case it is cellular.

**Gland cells** are frequently cylindrical, sometimes nearly spherical; Fig. 9. The material they secrete collects in them and is later expelled, either continuously, as in some glands, or at intervals, as in others.

**Blood** consists of many cells, called blood corpuscles, floating in a liquid; Fig. 10. This liquid is not formed like the mass of material separating the cells in cartilage and in bone, since it is not produced by the blood cells themselves.

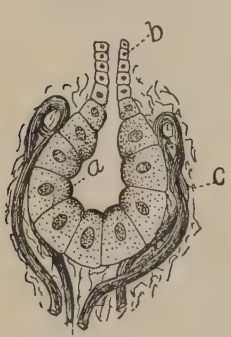



FIG. 9—A PORTION OF A GLAND

Showing at *a* the cells that secrete, at *b* the duct that carries away the secretion and at *c* the blood vessels supplying the gland.

**Nerve cells** differ widely in shape; some are nearly round, some are very long and some are irregular in outline. A common type has an angular body with a few much-branched prominences extending from the corners; Fig. 11.

**Fat cells** are like some of the other cells of the body, but pick up bits of fat from the blood, holding it until it is wanted; Fig. 12. These cells incidentally form a sort of cushion or packing for some of the soft parts of the body.

Although there is much diversity in the forms of cells in the body, each tissue is made of only a single kind which does a single kind of work. The size of cells varies widely. Some of the smaller cells of animals are not more than 0.003 mm. ($\frac{1}{8300}$ in.) in diameter, while the egg, which is essentially a cell, is sometimes several inches in diameter. The majority of cells in most animals vary from 0.008 mm. to 0.01 mm. ($\frac{1}{3100}$ to $\frac{1}{2500}$ in.) in diameter; Fig. 13.

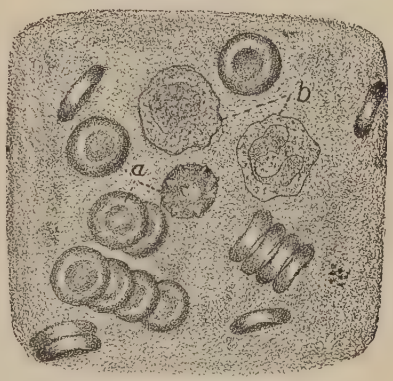



FIG. 10.—BLOOD

As it appears when put on a glass slide and highly magnified. At *a* are shown red corpuscles and at *b* white corpuscles or leucocytes.

**Structure of Cells.**—In recent years much attention has been paid to the more minute details of cell structure. As a result we now know that all cells, while differing in outward shape, are very much alike in their internal organization. Each one is filled with a semifluid substance called **protoplasm,** and this protoplasm is the part of the cell which is really alive. Protoplasm should not be thought of as life itself but it is the only material in which life is known to occur. When highly magnified, protoplasmic fluid always seems to contain fine granules, or it may look like a foam of extremely small bubbles or show a network of excessively minute lines; Fig. 14. At all times, if the cells under observation are alive and are not too much disturbed, movement of the protoplasm is evident. No one knows the cause of this motion; it can only be accounted for by saying that protoplasm is alive.

Within each cell is a specially dense bit of protoplasm called

the nucleus. This nucleus seems to be the center of the life and activity of the whole cell, for if deprived of it the cell cannot long continue to live. There are other parts of the cell, as is shown in Figure 14, for the cell is really a complicated bit of machinery.

FIG. 11.—A NERVE CELL OR NEURON
At *a* is shown the cell body; *b*, the nucleus; *c*, the axon of a nerve fibre; *d*, branching of the fibre; *e*, muscle fibres within which the fibre ends: *f*, a node in the fibre. (Barker)

The chemical composition of protoplasm is not definitely known, but certain elements—carbon (C), hydrogen (H), oxygen (O), nitrogen (N), iron (Fe), sulfur (S), calcium (Ca) and phosphorus (P)—enter into the composition of all kinds of cell protoplasm; other elements may occur in smaller quantities.

Protoplasm, then, should be remembered as the only living substance in the body. It cannot live long without a nucleus, neither can a nucleus live without the support of surrounding protoplasm.

The living protoplasm may be surrounded by a layer of greater consistency. This may be very thick, as in cartilage (Fig. 4); it may be very thin, as in the nerve cell, or it may be entirely absent, as in the white blood corpuscles; Fig. 10.

We may, therefore, define a cell in two ways. We may say that it is *one of the unit masses of which the tissues are formed*, or we may say that it is *a bit of protoplasm containing a nucleus and generally surrounded by a cell wall.* In either case, *the cell is the unit of life.*

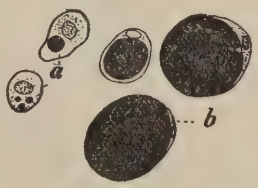



FIG. 12.—FAT CELLS

*a*, representing young cells just beginning to store fat; *b*, fully developed cells filled with fat.

**The Life of Cells.**—There are certain great differences between this unit of living matter and a non-living thing. Three distinguishing qualities belong to the living cell: (1) growth, (2) self-repair, (3) increase in numbers through self-division. These powers are possessed by no other material in the world save protoplasm.

The growth of a cell is in all cases brought about by material taken in from the outside. In the human body this material is food, which after digestion passes into the blood and is then taken in by the cells. This process will be described more fully later. In some of the very lowest organisms, where the whole animal is a single cell, solid particles may be taken into the cell through definite openings or "mouths"; Fig. 15. In others, the cell may change its shape so as to wrap itself about the particle to be taken in. But even in these instances the particles must be dissolved or digested before they can be built up into the protoplasm of the cells.

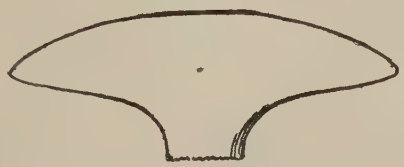


FIG. 13.—SHOWING THE RELATIVE SIZE OF A PIN HEAD AND A LARGE SIZED CELL

The small dot in the center represents the cell.

A machine in motion wears out, and the worn out parts must be replaced. Cells, too, wear out and new cells must be formed or new protoplasm is required to repair the old ones.

**Repair** and **growth** are brought about by one and the same process, the difference being that in repair, new material is added only as fast as the old wears away, while in growth new material is formed in excess of that which is worn out, the excess constituting the growth.

**Cell Division.**— Most living cells have the power of self division as shown in Fig. 16. This results in two cells like the original. In the human body, however, the cells do not separate from each other, so that by continued repetition of this process a large mass of cells is produced.

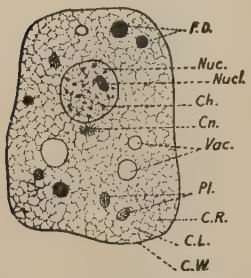



FIG 14.—A CELL SHOWING ITS INTERNAL STRUCTURE

*C.W.*, cell wall; *C.L.*, cell liquid; *C. R.*, cell reticulum; *Nuc.*, nucleus; *Nucl.*, nucleolus; *Ch.*, chromatin; *Cn.*, centrosome; *Vac.* vacuoles; *pl.*, plastids (pigment, chlorophyll, etc.); *F. D.*, fat drops (starch, gum etc. may be similarly present in plant cell).

**Reproduction.**— Every animal begins its life as a single cell — an **egg.** This cell repeatedly divides, the many cells remaining attached to each other. Thus the growth of an animal to adult size is not due to the growth in size of the individual cells making up its body but to increase in their number. The cells of the adult are not materially larger than those of the young. In time one or more of the cells from the body of the adult may be set apart as eggs, the process outlined above being started over again. This derivation of new individuals from single cells of a preceding one is called **reproduction.**

**The Cell as a Unit.**— We have thus seen that the body is made of organs, that the organs are made of tissues and that the tissues are made of cells. Is it possible to carry this division further? To this question we must reply that, so far as yet known, the cell is the final unit. It is true that the cell has parts—cell wall, nucleus, cell substances etc.—but no one of them can live by itself, while a complete cell may be an independent body and live an

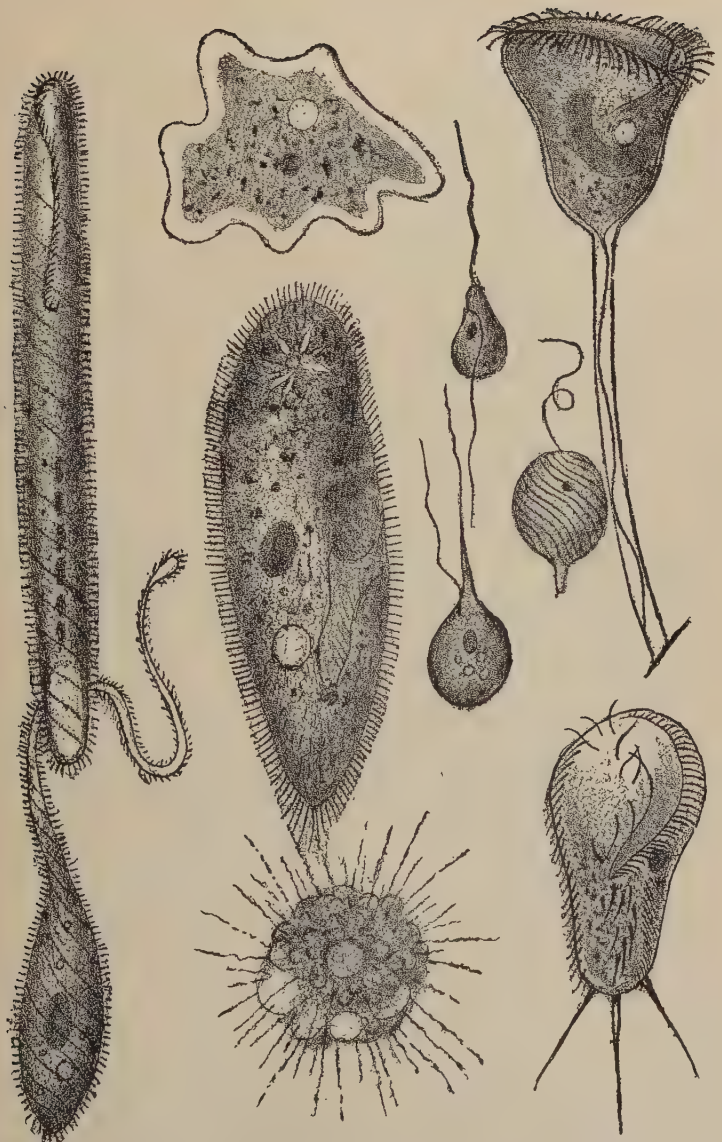


FIG. 15.—SHOWING A VARIETY OF ANIMALS, EACH OF WHICH IS A SINGLE CELL (HIGHLY MAGNIFIED)

independent life. Although our own bodies are composed of many millions of these cells, there are some organisms made up of one cell only. These are usually microscopic and are called **unicellular** animals and plants; although very tiny, each lives an independent life. Some of these animals are shown in Figure 15. They vary in shape and differ in structure. Some of them have "mouths"; others simply take their food in at any part of the body by allowing their protoplasm to flow around it. Some of them have organs for locomotion, others do not. Some have shells, while others have no covering at all. But each is a single cell, and each carries out its own life processes, such as *respiration*, *secretion*

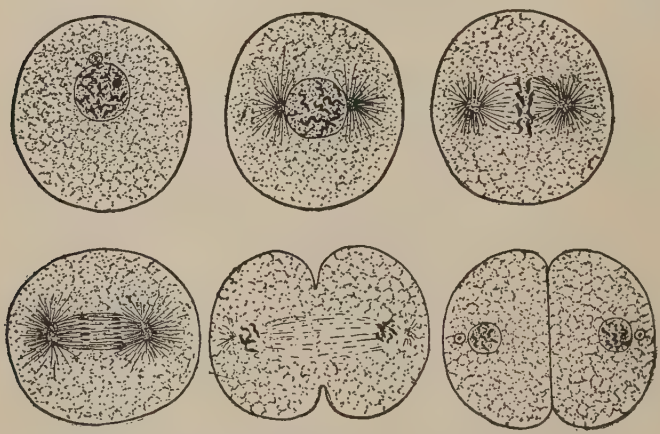


FIG. 16.—SHOWING THE METHOD OF CELL DIVISION

and *multiplication*. The cell cannot be subdivided into smaller units which would be able to sustain independent life.

Since such cells are the simplest parts into which living matter can be divided, we may call them the units of life and may regard our bodies as a combination of a large number of such units, considering the life of the whole body as the sum of the lives of its different cells. We should

constantly remember that it is really the cells which are the active, living parts. The combined lives of all these millions of cells make the life of the whole, much as the combined lives of the persons within a city make up its life.

## UNICELLULAR AND MULTICELLULAR ANIMALS

As we have seen, some animals are composed of a single cell. But this cell is able to carry on all the functions of life: it feeds, digests, respires, moves, multiplies and performs all the necessary duties of complete, individual life. In our own bodies there are many cells, but each is not capable of carrying on all the functions of life, and if separated from the others, would die. Each is able to do primarily only one thing; hence each is dependent upon the others.

It may be asked why we should have so many kinds of cells in our bodies, and why with us, too, one kind of cell could not serve all purposes. The answer is easy to give. A hermit can himself do everything needful to support his life: he can prepare his own food, make his own clothes and build his own shelter. But he can do this only because he lives very simply. When a family lives alone on the frontier the members divide the work among themselves, the husband doing the work out of doors, the wife that indoors and the children contributing their different shares. When several families come together, it will be found that some members of the community are more skillful in building houses, others in making shoes, others in dressmaking, still others in cooking and so on; so the people agree to divide their tasks and share the results of their work. In this way they may have better houses, better shoes, better clothing and better food than before, because each man does what he can do best. As the community grows this *division of labor* becomes extended until, in a large city, each person does only a very small part of the work necessary to supply him with the things he needs. But he can do his

own work well because he has only one thing to do. The life of a city is of much higher grade than that of a pioneer family; its population has many more luxuries and accomplishes much more, all because of this division of labor. The people become more and more dependent upon each other, but for just that reason they are better served.

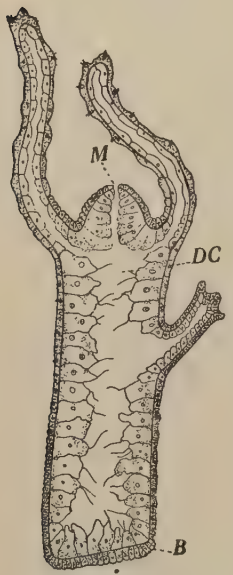



FIG. 17.—A MULTICELLULAR ANIMAL (HYDRA)
Showing its body to be made of many cells that are not all alike, *B*, base for attachment; *M*, mouth; *DC*, digestive cavity.

So it is among organisms. Where one cell does everything, the life is simple and on a very low scale. Each cell can feed itself and perform all the necessary functions, but the whole life is only one of growth and reproduction. As the cells become more abundant, they also become unlike. Each takes upon itself certain duties, each contributes to the good of the other cells, and each receives aid from the others. In Figure 17, for example, we have a simple animal in which two kinds of cells are shown. Those in the center take care of the digestion of food, while those on the outside protect the animal from external injuries. The entire organism is thus much better served than it would be if each cell had all the varied duties to perform. The life of any animal is the sum of the lives of its cells, and with many kinds of cells all working together for a common good, a higher grade of activity is produced than with each working for itself alone. *Division of labor goes hand in hand with a rise in the scale of accomplishment and results in a superior type of life.*

## CHAPTER II

## CHEMICAL COMPOSITION OF THE BODY

Everyone feels that he knows the difference between an object that is alive and one that is not alive; and certainly there is no difficulty in distinguishing between them when we are considering such things as dogs and stones. But how can we tell whether or not a dried pea is alive? We might find out, perhaps, by planting it. If it sprouted, we should know that it had life, but we could not tell by its appearance nor by pulling it to pieces.

When it proves impossible to tell the nature of a material from surface examination or by dissection, the chemist is usually called in to settle the question. It would be natural to suppose that living and non-living bodies are made of different chemical materials; that the living body contains some hidden, secret thing which the non-living lacks.

### ELEMENTS

For a century or more chemists have been at work trying to divide things into the simple materials of which they are made. Those simple materials which cannot be further divided are called **elements.** Out of one or more of them, all the various kinds of material in the world are made. Rather to our surprise we find that there are but a small number of elements, only about eighty-one being known of which less than twenty make up most of the common things. This seems a remarkably small number until we learn how many different things can be made from the same ele-

ments. Think, for example, of sugar, alcohol, glycerine, kerosene oil, starch, benzine, paraffin and fat. How unlike they are! In spite of their apparent differences, all these substances are made of carbon, hydrogen and oxygen; each one contains these three and nothing more; they differ only in the various proportions of the elements. In a similar way, by varying the amount of each element put into any combination, all the different substances in the world are made from the eighty-one elements. This is true of animals as well as of all other material things. The fact that the body weighs just as much immediately after as it does before death, shows that no substance is lost at death. There is really no difference between dead-weight and live-weight; clearly then the same elements enter into living and dead bodies.

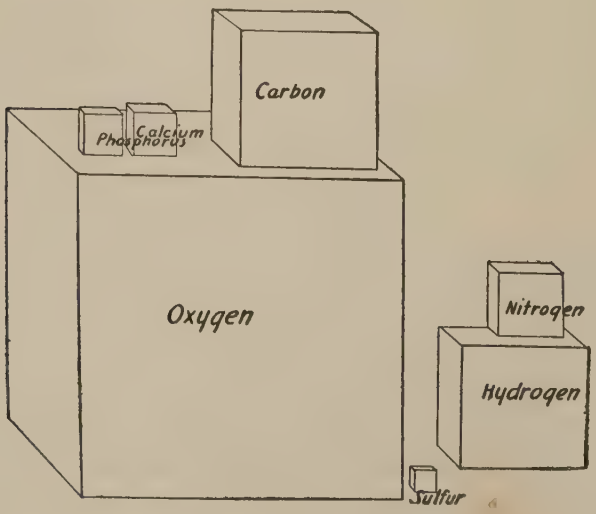



FIG. 18.—DIAGRAM ILLUSTRATING THE RELATIVE AMOUNTS OF SOME OF THE ELEMENTS IN THE CHEMICAL COMPOSITION OF THE BODY.

Water, for example, as it leaves the body as perspiration, is made of hydrogen and oxygen, the same as water from a faucet. The juices formed in the stomach are partly made of hydrochloric acid, the same as that used in various manufacturing processes. Much of the material in bones is lime; some of the material in blood is iron, and it becomes red when mixed with oxygen, the same as iron does when it rusts. Salt is easily noticed in perspiration and tears, and has the same composition as table salt.

Living matter contains but a small number of the seventy-seven elements referred to above; those commonest in the body are carbon, hydrogen, oxygen, nitrogen, calcium, phosphorus, sulfur, sodium, chlorine, fluorine, potassium and iron. The following table shows approximately the percentage in which each occurs:

CHEMICAL COMPOSITION OF THE BODY

| Elements | Symbol | Percentage | Elements | Symbol | Percentage |
|---|---|---|---|---|---|
| Oxygen | O | 72 | Chlorine | Cl | .085 |
| Carbon | C | 13.2 | Fluorine | F | .08 |
| Hydrogen | H | 9.1 | Potassium | K | .026 |
| Nitrogen | N | 2.5 | Iron | Fe | .01 |
| Calcium | Ca | .25 | Magnesium | Mg | .0012 |
| Phosphorus | P | .15 | Silicon | Si | .0002 |
| Sulfur | S | .02 | Copper, Lead and Aluminium in very small quantities | | |
| Sodium | Na | .3 | | | |

These are the same chemical elements which we should find if we analyzed materials all around us in nature; e. g. air, water, soil or rocks. The living body is thus constructed of the same materials as are found in non-living, inanimate bodies. But there must be some difference. What is it?

## THE CHIEF CHEMICAL COMPOUNDS IN THE BODY

If the materials used in building a city block were chemically analyzed, many of the elements found would be the same as those present in the body. But when we talk about the construction of a building, we never mention the chemical elements of which it is composed; we speak rather of the *compounds* of these elements. Beams, piping, windows, chimneys, furnaces, flooring and doors are all parts of the building, but they can be roughly classified as made of wood, iron, brick or stone. Similarly, in speaking of our bodies, mention is seldom made of the chemical elements in them, but of the combinations in which the elements most frequently occur.

There are three compounds that are of supreme importance in living animals. They constitute almost all the essential materials in our bodies. Since they are also the principal constituents of our foods, they are called **food stuffs.** These compounds are: (1) **proteids,** (2) **carbohydrates** and **(3) fats. Water** and **salts** are also necessary.

**Proteids** (Albumen, Myosin, Gluten, Casein, Legumen, Fibrin). —Proteid is made up chiefly of four elements: carbon, hydrogen, oxygen and nitrogen, though sulfur and phosphorus are present in small quantities. Proteid occurs in all animal and vegetable organisms. For example, in the human body proteid comprises 38.3% of the lens of the eye, 16% of the muscles, 12% of the liver, 9% of the blood. These percentages are not so small as they seem, since the greater part of all tissues is water. The human body, taken as a whole, is nearly 67% water, and the proteids form a large proportion of the rest.

**Proteids as Tissue Builders.**—The proteid which the body contains must either be obtained directly in foods or be made from them. Now the body is quite unable to make proteid;

hence it follows that proteids form an absolutely necessary part of our food. We must eat a sufficient amount of proteid or we shall starve, no matter how much other food we eat. Proteid is needed in all the working parts of the body. Muscle and blood are pre-eminently active. Performing absolutely vital functions every moment of our lives, they are constantly exposed to "wear and tear" and unless they were repaired would become exhausted and worn out. The body must have new proteid for repair purposes and the proteid must be provided by the use of proteid-containing food. This food may be obtained from many sources. Some proteids come from animal and some from vegetable materials. That from meats is called *myosin*; that from eggs is *albumen*; that from milk is *casein*; that from wheat is *gluten*; that from beans is *legumen*. But although differently named and differing in value to the body, all these forms of proteid serve as a food which can replace and repair the worn-out parts of the body. If we remember that proteids alone can thus replace worn-out tissue, we shall understand their fundamental importance.

One naturally and correctly feels that proteids from animal sources are probably most like that of the human body, and so can be used with better results. Furthermore, as all substances taken as foods must be masticated, swallowed, digested, absorbed into the blood, carried over the body and then received into the living cells and made a part of the body substance, it is easy to imagine that some proteids undergo these changes more readily than others, and so are more valuable.

In a later chapter dealing with foods the differing values of various proteids will be discussed. Some kinds, taken alone, will not support the growth of an animal at all; others seem to furnish every needed substance, even when quite small quantities are taken. Very extensive and expensive studies have been made in recent years in the analysis of all kinds of proteids and other food substances, together with

their digestibility and final values. Human beings have been used in these experiments so that the results are of great value.

**Proteids as Fuel.**—To keep an engine running it is not enough that it be kept in repair; there must be a fire in the fire-box. In one respect the body differs from an engine: while the iron of which a locomotive is made cannot be used as fuel, the proteids of which the body is made can be burned. By being burned we mean here, united with oxygen, a phenomenon which chemists call *oxidation*. Foods in the body unite with oxygen and this may be called "burning," though the oxidation is not so rapid in the body as in an actual fire, and there is, of course, no flame: but the union with oxygen is similar, heat is developed in a similar manner and the final results are much alike. Proteids have a double value: (1) they are burned in the body and (2) they build up tissue. When all the proteid eaten is not needed to build up or to repair the tissue, the rest may be burned to furnish heat and force.

In using proteids for fuel there is, however, one disadvantage which limits their value as food. After any fuel is burned, certain waste products always remain. When a fire burns in a locomotive, a vast amount of smoke and gas arises and passes off through the smoke-stack, while ashes are left to be raked down through the grate and thrown away. The fire will not continue to burn unless these waste ashes and gases are removed. In the body, too, as a result of the burning, gases and other wastes arise. The gases pass off readily enough through the lungs. But there is a more troublesome residue that corresponds to the ashes. We have noticed that proteids contain some of the chemical element, nitrogen. After the burning of the proteid in the body, this nitrogen becomes a waste product and can be disposed

of only as an excretion of the kidneys. The more proteid we burn for fuel, the more of this waste there is, and hence the greater the work of the kidneys. If, therefore, we eat large amounts of proteid, the kidneys have extra work to do; indeed, it is believed that some kidney troubles are produced or at least aggravated by overtaxing those organs from the consumption of too much proteid.

Nevertheless, the body must continue to burn fuel in order to keep up its life; it can no more live without burning fuel than the locomotive can run without its fires. If it is not wise to burn great amounts of proteid, what can the body use as a source of the necessary heat and power? If there is some kind of food that furnishes the required energy without leaving behind nitrogen waste materials, it will evidently be of much value. There are two such classes of foods: carbohydrates and fats.

**Carbohydrates.**—Although starches and sugars seem very different, they are really much alike in chemical composition and may be converted, the one into the other. It is especially easy to change starch into sugar. The similarity in their chemical formulæ is very noticeable. Fruit sugar is $C_6 H_{12} O_6$; starch is $C_6 H_{10} O_5$. Starches are always turned into sugars and dissolved before they are taken from the intestine into the blood. From the blood vessels the sugars penetrate into all the tissues and are soon very widely distributed.

Sugars and starches of various sorts are so commonly seen that one should be warned against thinking of these substances, after their assimilation into the body, as having their usual appearance. Both may be present in solid or crystalline form in the cells of plant leaves, stems or roots; but not so in the cells of any kind of animal. The nearest to it is a substance found especially in the cells of the liver and in muscles and called *glycogen*. The chemical formula of glycogen is the

same as that of starch $(C_6H_{10}O_5)_n$, though the two substances have little else in common. Glycogen, too, varies much in the amount stored up when an excess of sugar is eaten, and disappears when one is hungry.

**Fats.**—Tallow, lard, cream, olive oil etc. furnish another fuel that can be burned without giving a nitrogen waste. These fats are derived from both animal and vegetable foods and though made of the same elements as carbohydrates (C, O and H), they are more complex. Fat is plentiful in the body in both fluid and semi-fluid condition. It is absorbed by the blood from the intestine in a fluid condition, is carried around the body in the blood and is eventually taken from it and deposited in various parts of the body.

Fat occurs in masses among the muscles and just beneath the skin; it forms a cushion for the eyeballs at the bottom of the eye sockets; it is present among the folds of the intestine; it fills up certain crevices in the exterior of the heart muscle and is deposited in the central marrow of the larger bones.

Evidence of these facts we have all seen many times in food markets where meats are displayed. No meat is mingled with so much fat as pork; hogs have famously large appetites and, at the same time, sluggish habits. A result of this is that only partial use of the fats is made for energy or heat production, thus leaving excessive fat to be stored. A farmer rather easily controls the degree of fatness of horses, cattle, chickens, and other animals by attention to their food and exercise; and their food does not necessarily contain fatty substances, for many animals become fleshy though eating nothing but the proteids and carbohydrates in hay and grain.

**Uses of Carbohydrates and Fats.**—The body must at all times be kept warm and is constantly using power in muscular activity. Heat and power may roughly be said to constitute energy, and in order to live the body must have not

only material for growth and repair, but also a supply of energy.

Fat is a form in which the body frequently stores fuel food for future uses. If the body has an abundance of food at one time, it need not all be used immediately but may be laid aside as fat, to be called into use at some later time when the body may not be able to secure or to take up the necessary amount of food.

After a long sickness a patient's eyes are likely to be sunken and the ribs to show through the skin. This is due to the fact that during his illness he has not been able properly to digest and assimilate food, and has been calling upon the stores of fat in his body to support life and furnish him with warmth and energy.

A tallow candle is made of fat and when it burns, gives out heat. The Eskimo can warm his hands by holding them over the burning candle; but he prefers to eat the candle and let it warm his body through internal oxidation. In this way he does not lose any of the heat. It would be perfectly possible, though expensive, to warm our houses by burning lard, olive oil or butter in our furnaces. So, too, we might burn starches or sugars for the same purpose, or might run an engine with the force they would furnish when burning. Whenever these substances are oxidized, they liberate much energy and if they are oxidized in the body, they liberate this heat and force within it.

Carbohydrates and fats do not, however, yield equal amounts of energy to the body, the carbohydrates giving us, weight for weight, only about half as much as the fats. Both are composed of the same elements, carbon, oxygen and hydrogen, and it is natural as well as quite worth while to ask why one yields so much more than the other. The answer lies in the relative amounts of carbon which these foods contain; the chemical formula for starch is $C_6H_{10}O_5$; for sugar, $C_6H_{12}O_6$; for fat, $C_{51}H_{104}O_9$. Now, in the changes

which these undergo in the body much of the hydrogen may combine with the oxygen to form water, $H_2O$, while the carbon also unites with oxygen to form carbon dioxid, $CO_2$. It is this combining with oxygen, this *oxidation* of materials, which results in heat, just as it is when the carbon in burning wood unites with oxygen of the air, and gives off heat in making the combination.

As will be noticed from the above formulæ, fat contains fifty-one parts of carbon, while sugar contains only six. Heat is produced when the carbon combines with oxygen, as we have said. In sugar the carbon already has six parts of oxygen combined with it and cannot combine with very much more. In fat, however, there are fifty-one parts of carbon, and only nine parts of oxygen combined with it. In fat there is therefore a much larger amount of carbon which can be combined with the oxygen of the air than there is in sugar; when fat is burned there is a large amount of oxidation and hence a far greater amount of heat given off. Indeed, fat furnishes a larger amount of heat than any other food.

Thus carbohydrates and fats furnish us with a quick and profitable source of energy. It must be clearly understood, however, that neither of them is of any value in tissue building. Neither muscle nor brain nor gland nor any other active tissue can be made or even repaired by them.

**Gelatin.**—Most meat foods contain another material known as **gelatin,** which in its refined form causes the hardening of most of our table jellies. It is obtained from connective tissues (see page 13) by boiling. In its chemical nature it resembles proteid, but it will not take the place of proteid in tissue building. It may be used by the body as a source of energy and hence has much the same function as carbohydrates. In eating jellies one is likely to be deceived into thinking that he is eating more than he is, since they contain much water and are bulky, considering the small amount of actual food in them.

## METABOLISM

All the materials of which living bodies are composed come from the soil and from the air. All vegetable foods surely come from these sources; animals eat plants or eat other animals which, in turn, live on plants. After being taken into the body the foods go through certain changes, the final result of which is that part of the food, at least, is transformed into living tissues. These changes constitute what is generally spoken of as a "building up" process, which means that complex substances are made of simple ones. After these tissues have severally fulfilled their functions, serving as muscle, brain, fat, bone or gland, as the case may be, they gradually wear out; as this occurs they are "broken down" from their complex condition into simple forms again.

In living matter, there occur two types of changes—a building up, or **anabolism,** and a breaking down, or **katabolism.** As a result of this breaking down process the substances which have been alive and have acted at the bidding of our wills become again inactive and non-living. Gradually all parts of our bodies—heart, brain and everything else—become once more a part of the soil and air, just as they were before they were first taken up by plants. The changes are long and complex. Some take place in the body and some outside the body, for materials are sometimes excreted before they are completely broken down. The changes that take place in the body, the building up and the breaking down taken together, are spoken of as **metabolism.** *Metabolism is thus a name for the chemical changes which are taking place in living tissues.*

Many factors combine to regulate each of these processes. Katabolism (destructive change), for instance, is increased by excessive work, by poor nutrition, by loss of

sleep, by nervousness, by various diseases and by the action of certain poisons and drugs, such as opium, chloral and alcohol. It seems strange that men should consciously persist in the use of some foods, and especially some drinks, which inevitably bring about this increased katabolism in important organs; that they should continually expose themselves to weakening processes which the building up processes can counterbalance with difficulty, if at all.

**Growth.**—The body is evidently a very active center into which large amounts of material are constantly entering in the form of food, drink and air, and from which, at the same time, large amounts are constantly being eliminated. Body substance is being constructed and destroyed at the same time, and if these two processes are going on at the same rate, the body neither increases nor diminishes either in weight or efficiency. Such a condition is commonly spoken of as one of **metabolic equilibrium.**

If, on the other hand, the destructive processes take place more rapidly than those of construction, the body will lose in weight or efficiency, and if this condition of things continues long enough, death must result. When the constructive processes in the body go on faster than the destructive or wearing away processes, the result is an increase in weight or in efficiency. The growth of the body, then, is the result of the excess of constructive changes over destructive changes.

Anabolism exceeds katabolism during childhood and early youth; but after adult life is reached, under ordinary circumstances the body maintains itself in metabolic equilibrium. This latter condition constitutes what is generally spoken of as **health,** the maintenance of which should be a matter of careful, serious attention as long as life lasts.

## CHAPTER III

## FOODS AND FOOD HABITS

It is important for us to know the real nutritive value of the foods that we commonly eat. In this study it should be constantly borne in mind that for the proper support of life we must have a considerable amount of proteid since this material alone builds up the tissues of the body. Carbohydrates and fats can be used only as sources of heat and force.

Scientific men who spend their time studying the fossils of animals which lived ages ago, and which are known now only by their imperfectly preserved skeletons, tell us that they can determine what the animal ate and much about the rest of its body if they can find the teeth. We cannot say what it was originally intended that man should eat; certainly it was not the kind of food which he eats now, for many of our foods are recently discovered. But we can say that his teeth are adapted for cutting, tearing and grinding, and that his habits are **omnivorous**; i. e. he eats almost all kinds of foods. In the preparation of foods, he has contrived methods which change their flavor, their appearance and their smell. He is able to have summer foods in winter, and spring foods in the autumn. Since he eats such a variety of things under such different forms, the queries naturally arise: Which are the best of these foods? Which kinds are most easily digested? Which yield the most nutriment?

### FOOD HABITS

We sometimes think that our foods are rather monotonous and wish some new kinds might be found; yet it is

interesting to note the great variety of foods on which people live. Americans do not eat the same foods as Japanese, and yet one nation thrives as well as the other. The Spartans subsisted mainly on dried fruits and honey; the Chinese employ rice as a staple article of diet, and many of the Italians make a similar use of chestnuts. White caterpillars, seal or whale blubber, tallow candles, leather, shark's fins, grasshoppers, earthworms, deer's sinews, dogs, cats, rats, are choice articles of diet with different people. These seem odd preferences, but are they more so than oysters or crabs in their shells, and shrimps or frozen cream, all of which are common with us?

The fact is that with the exception of the woody tissues of plants, almost any part of an animal or plant may yield nourishment, and under some conditions serve as food. From an endless list, our selection depends chiefly upon the customs of the community in which we live, on our taste and on the cost. A person is always mistaken when he thinks that any particular kind of food is a necessity. We can all adapt ourselves to a wide variety and it is best to become accustomed to the kinds of food most conveniently obtained under the ordinary conditions of living in one's own community.

Some foods are more useful than others; some are expensive, some difficult to digest and some dangerous to health. It is fortunate for the majority of people that the expensive foods are really no better than the cheaper ones; indeed, expensive kinds are usually rich foods which, in the end, are almost sure to produce digestive troubles.

### THE VALUE OF DIFFERENT FOODS

Many things have to be considered in determining what it is best to buy for the table. Certain very good foods do not grow in some parts of the country, and this makes them expensive. Other foods are expensive even where they

grow because of the cost of raising and refining them. We like to have them on the table because they are "choice." Does their nutritive value, however, compensate for the additional cost? Some foods are attractive but not nutritious, and vice versa. To-day people are engaged in a wide variety of occupations; their bodies are worn out in different ways; then, too, some people can afford to pay twice as much, perhaps ten times as much as others for their food.

In considering these matters, we will take them up from the standpoint of the three primary food stuffs.

**Proteid Yielding Foods.—**

PERCENTAGE OF PROTEID IN SOME COMMON FOODS

| | | |
|---|---|---|
| Cheese, skim | 44.8 | ——————————— |
| Poultry | 21. | ———————— |
| Egg, white | 20.4 | ———————— |
| Beef, lean | 19.3 | ——————— |
| Mutton, lean | 18.3 | ——————— |
| Veal | 16.5 | ——————— |
| Salmon | 16.1 | ——————— |
| Egg, yolk | 16. | ——————— |
| Beef, fat | 14.8 | ——————— |
| Mutton, fat | 12.4 | ——————— |
| Milk | 3. | — |
| Peas and Beans | 24. | ———————— |
| Flour | 10.8 | ——————— |
| Bread | 8.1 | ——————— |

From this table it will be seen that animal foods, in general, furnish the largest amounts of proteid. Whenever we eat meat, eggs, milk or cheese, we get a great deal of this food stuff. We learn, too, that though we may eat the same amount of food each day, we do not by any means always eat the same amount of proteid. Fat pork often contains much less than half the proteid per pound that lean beef

does, and not more than three-fifths as much as fat beef. Nevertheless, we eat one kind of meat for dinner one day and another the next, and since we eat about the same amount of each, we certainly obtain more proteid food with some meals than with others.

DEMONSTRATION.—Boil an egg for ten minutes and remove the shell. Cut in halves to show the coagulated albumen and the yolk.

The amounts of proteid in different vegetables also vary greatly: peas and beans furnish an exceptionally large

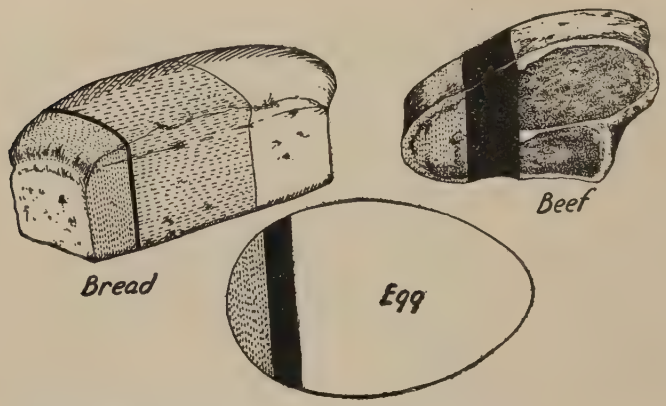



FIG. 19.—GRAPHIC REPRESENTATION OF THE FOOD VALUES OF BREAD, BEEF AND EGGS

Fats are shown in black, carbohydrates in horizontal dotted lines, and proteids in vertical dotted lines. Other parts are water.

amount of proteid; cereals, such as wheat, oatmeal and corn meal have less, but still contain a large quantity; vegetables and fruits, such as cabbages, lettuce, tomatoes and asparagus hold very small amounts, yet we often substitute one of these foods for another. These vegetables and fruits are useful as promoters of digestion, or because they have a pleasant flavor, but they must not be

looked upon as furnishing any great amount of real food.

It is clear, then, that the common kinds of foods differ much in their nutritive value, and though ordinarily we do

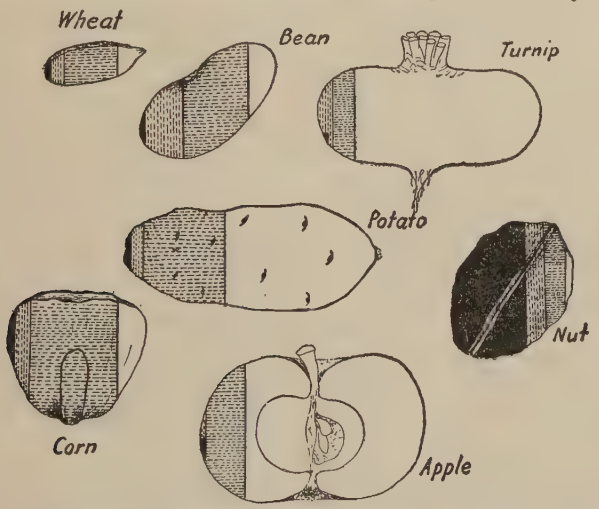



FIG. 20.—SHOWING THE NUTRITIVE VALUES OF DIFFERENT FOODS
The shading as in Figure 19.

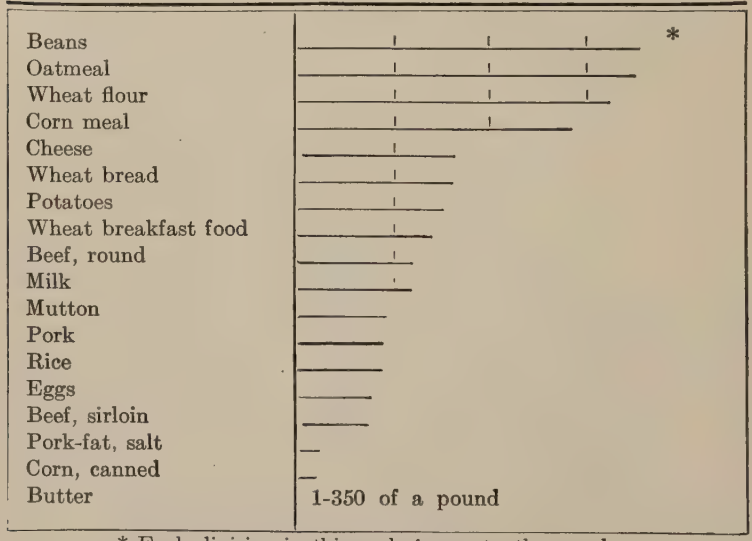
not think of this fact, we should bear it in mind if we would properly regulate our diet. So far as proteid is concerned, this is graphically shown by Figures 19 and 20.

**Relative Expense of Proteid Foods.**—Few things contribute more to health and happiness than intelligence in choosing foods. In the selection each person will be guided by a number of considerations. Some nutritious foods can be obtained at much smaller cost than others; for instance, a quarter of a pound of cheese usually contains as much proteid as half a pound of lean meat or three-quarters of a pound of fat meat; half a pound of beans or bread contains as much of the needed proteid as a pound of fatty meat, though its cost is much less; Fig. 19. Skimmed milk contains as much proteid as whole milk, the cream being chiefly fat and in some respects of

much less value as nutriment than the casein in the skimmed milk. Vegetables, in general, such as cabbage and lettuce, contain extremely little nourishment of any kind. As a rule, it is better to purchase foods which have large quantities of the necessary substances in them than those which have small amounts. If we should eat enough of the latter kind, we could, of course, obtain all the food we need; but it would compel the digestive organs to do a quite unnecessary amount of work.

The following list, giving the amount of proteid which can be bought in different forms for ten cents, will be of value as a guide to an economical purchase of table supplies.

**AMOUNT OF PROTEID PURCHASABLE FOR TEN CENTS**



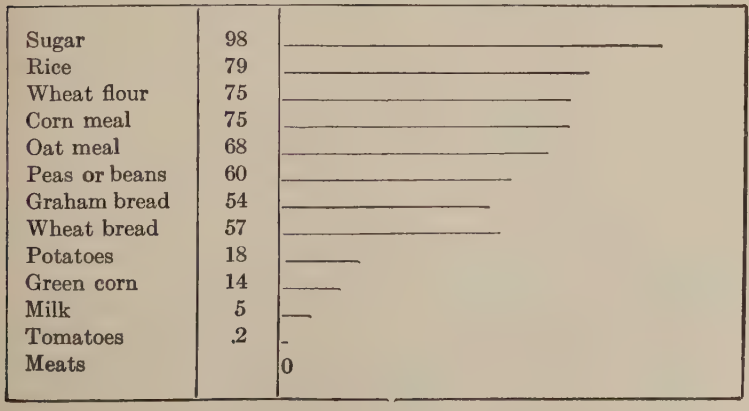

* Each division in this scale is one-tenth pound.

**Carbohydrate Yielding Foods.**—Carbohydrate yielding foods are almost wholly vegetable, as animal substances furnish only a small amount of starch or sugar. Milk, containing

4% milk sugar, is the only important animal source. All foods of vegetable origin, especially the cereals, wheat, corn, oats, etc., furnish some starch. Peas, beans, and potatoes all yield moderate amounts of starch only (Fig. 20.) This is because potatoes contain much water, while peas, beans, etc., are composed one third to one fourth of proteid. Leafy vegetables, *e.g.*, cabbage, and lettuce, yield almost no food proper.

Vegetable foods also contain sugars, though they are not so common as starches and hence not so cheap. Sugar cane and sugar beet provide us with the greatest quantity, this sort of sugar being called *saccharose*. Fruits contain considerable sugar of a type called *fruit sugar*, *glucose* or *dextrose*. It is not so sweet as cane sugar, but its food value is just as great. Chemists can easily make this form of sugar from starch, and can produce it in this way quite cheaply. This fact has caused it to be used frequently in the adulteration of cane sugar and very clear, colorless syrups. The fact that it has very little sweetening power makes it necessary to use more of it to produce the desired sweet taste; it is, therefore, an undesirable adulterant for cane or for beet sugar.

**PERCENTAGE OF CARBOHYDRATES IN COMMON FOODS**



**Fat Yielding Foods.**—Fats are present in both animal and vegetable foods, although the larger amounts come from animal sources, and the most common fats are those in meats. Lard is a fat from pork, and butter is simply the fat taken

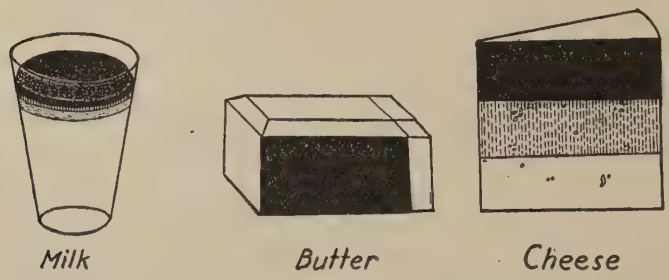



FIG. 21.—SHOWING THE FOOD VALUE OF MILK, BUTTER AND CHEESE
The shading as in Figure 19.

from milk, which is an animal product; Fig. 21. From vegetable products, e. g. olives, corn and nuts, more or less fat is obtained, generally in the form of oil.

**PERCENTAGE OF FATS IN COMMON FOODS**

| | | |
|---|---|---|
| Butter | 85 | |
| Salt pork | 60 | |
| Mutton | 22 | |
| Beef | 20 | |
| Fish | | Varies from .2 to 20% |
| Eggs | 10 | |
| Oatmeal | 8 | |
| Milk | 3.5 | |
| Corn meal | 2.2 | |
| Rice | .4 | |
| Beans | .2 | |
| Wheat flour | .1 | |
| Peas | .1 | |
| Potatoes | .1 | |

**Some Characteristics of Fats.**—Some fats, e. g. butter, are very pleasant to taste, while others, like castor oil, are decidedly unpleasant; some are easily swallowed, while others can be swallowed only with difficulty. The reason for this is that three different kinds of fatty materials are mixed together in the ordinary fats of our foods; one of these, called *olein*, melts at 23° F. (–5° C.); a second, *palmatin*, melts at 113° F. (45° C.); and a third, *stearin*, melts at 140° F. (60° C.). It is easy to see that the more olein a fat contains the more easily it can be melted. Olive oil is mostly olein and is melted at ordinary temperatures, while beef tallow contains much stearin and is solid even at the ordinary temperature of the body. Butter and lard are quite soft because they contain a large proportion of the easily melted olein. It is well to remember also, that the easily melted fats are the most readily digested.

Fats constitute an extremely important part of our food since they are so easily digested and yield so much energy. All fats, whatever their special natures or flavors, serve much the same purpose.

**Vitamines.**—Until very recently it has been believed that the three food materials above discussed, together with salts and water, were all that is necessary for an ample diet, and that new protoplasm is readily made from them alone. Certain diseases, *e.g.*, a form of neuritis ("beri-beri"), an intestinal disorder (scurvy), and rickets, were explained as due to the use of incorrect proportions of the foods already mentioned.

It is now clearly proven that substances called *vitamines* must also be eaten and when used, the illnesses referred to do not occur, or if present, are cured.

Vitamines are found in the seed coats of most cereal grains, in yeast, in whole milk and butter, in eggs, in leafy vegetables (especially spinach), and in the juices of commonly eaten fruits, *e. g.*, oranges, apples, etc. These substances are destroyed in boiled milk, and as fruits are heated when canned,

**Cereals**—The various breakfast cereals are all excellent foods and rank with bread in food value. They are made mostly of wheat or oats, both of which contain much proteid and starch; Fig. 22. They are somewhat lacking in fat, but if eaten with cream form an almost perfect food.

**Rice** contains less proteid than wheat and, like it, very little fat. It should, therefore, be eaten with some food containing more proteid, e. g. meats, cheese or beans.

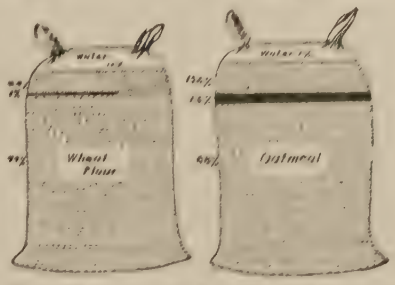



FIG. 22. SHOWING THE FOOD VALUES OF WHEAT FLOUR AND OATMEAL. Shading as in Figure 19.

**Beans** and **peas** contain very large amounts of proteid, as much as meats or even more. Although they also hold considerable starch, they are to be looked upon chiefly as a source of proteid. To form a balanced diet they should be accompanied by some food containing starch and fats, such as bread and butter. Peas and beans are difficult to digest and should be eaten somewhat sparingly.

**Potatoes** have a relatively small food value. They contain only 1.8% of proteid, 14.7% of starch and little fat; Fig. 20 They are very poor foods if used alone, and must be eaten in great quantities to supply the requisite amount of proteid They do, however, furnish a cheap source of starch and are, therefore, valuable to accompany other foods such as meats, cheese, beans etc.

**Vegetables**, as a rule, contain so little real nutriment that we can scarcely consider them foods at all. They are valuable because of their pleasant flavors, which stimulate the action of the digestive glands.

**Fruits** furnish about the same elements as vegetables. They have pleasant flavors which excite proper activity in

the digestive organs. It is, therefore, useful in regulating digestion, but does not furnish much nutriment.

**Nuts** contain fat and in some cases much sugar and proteid; Fig. 20. In spite of the fact that they are used extensively by vegetarians, they are, unfortunately, hard to digest.

**Confectionery** is a real food and not simply a luxury. It furnishes fuel food only, but this in large amounts. A pound of candy will yield about two-thirds of the fuel needed by the body during a day.

### THE AMOUNT OF FOOD NEEDED

Even when the body seems to be perfectly quiet it is doing much work. The heart is beating, the blood is circulating, the chest is moving. Much heat is constantly demanded to maintain internal temperature and to counterbalance that given off from the surface. The body, even when quiet in sleep, is giving off heat about as fast as a sixteen-candle power electric lamp; and when awake, but resting, as much as a twenty-candle power lamp. The total amount of energy expended in various ways by the body may be better appreciated when it is noted that an ordinary person while remaining quiet for a whole day uses up an amount of energy equal to that required in climbing a mountain five thousand feet high. This measurement of energy is usually expressed in terms of heat units, called **calories.** A calorie* is the amount of heat required to raise the temperature of one kilogram (about one pint) of water about two degrees F.; and the resting body uses from 2000 to 2300 of these units in twenty-four hours. If a man rises from his chair, walks about eight feet and returns, he uses about one unit. When a person is working he liberates more heat and expends more energy than when quiet; in order to do this he must oxidize more food. The working man may use two to four times as much food as one

*This is the *large* calorie; not the small one, which is only $\frac{1}{1000}$ as great; *i.e.*, the amount of heat required to raise the temperature of one gram of water 1° C.

resting, and a fair day's work would require an extra amount of fuel food equal to about one pound of sugar or starch, or about one-half pound of fat. A working man's diet should contain more carbohydrates and fats but little if any more proteid than that of a person of sedentary occupation. A large person needs more food than a small one and an adult more than a child.

Hence no fixed amount of food would be the correct one for every person. The amounts of some common foods in either of the following rations represent approximately what is required each day by an average adult person doing a moderate amount of work:

### A DAY'S RATION

**I.**—Lean meat, ½ lb. (a piece as big as a man's hand)
Potatoes, 1 lb.
One glass of milk
Bread, ½ lb. (¼ of a small loaf)
Butter, sufficient to go with the bread

**II.**—Bread (with butter), 1 lb.
Milk, 1 pt.
Cheese, 2 oz.
Eggs, 2
Fruit

If one eats three meals a day, the amounts mentioned in either list given above should, of course, be distributed through the three meals. The rations outlined differ slightly in the total amount of food they contain, but they are nearly equivalent in nutriment. The amount of proteid in each is less than some think necessary, and more than others advise.

**Overeating.**—Overeating may result from eating too much at a meal or from eating too frequently. Undoubtedly Americans suffer from eating too much. The difficulty of saying just how much a person should eat makes it equally

difficult to define what is meant by overeating. In general, if one eats till he feels surfeited, or if he adds a dessert after he has satisfied his appetite, he is overeating and will probably suffer for it. A dessert is frequently a misfortune, since it is added to a meal to please the sense of taste rather than to satisfy the appetite. A growing boy or girl needs more food than an adult, and overeating, though a common fault with grown people, is not likely to occur with children.

**Frequency of meals.**—Most Americans are in the habit of taking three meals a day and regard this as necessary to health. In reality frequency of eating is simply a matter of habit. Some nations are in the habit of taking four or even five meals in a day, others eat only two, while savage tribes eat very irregularly, often only once in two or three days, without suffering in health. No rule can be given as to the proper time that should elapse between meals. It is unwise, however, to eat too frequently. Breakfast, if eaten immediately after the long sleep, should ordinarily be the lightest meal of the day, since the digestive organs are not ready to begin work as quickly as the brain. The hearty meal should be preferably at the close of the day's work, and should be followed by rest for an hour or more. Mental work immediately after eating seems to interfere with digestion less than does muscular exercise. A little food before going to bed may not be injurious, and is frequently advantageous in enabling one to sleep more easily. A hearty meal before retiring is, however, not advisable. Among other bad effects it is likely to produce unpleasant dreams.

**The Appetite as a Guide in Eating.**—The only guide which nature has given us as to the amount and kind of food we should eat and the liquid we should drink is the appetite. Lack of food produces hunger which is felt in the stomach, and lack of water produces thirst which is felt in the throat.

When a person is in health the appetite is a tolerably safe guide as to the amount he should eat. This is true only provided he distinguishes between a real desire for food and a desire to please the taste, as for example, when eating candy. If he should continue to eat and drink after his appetite is appeased, he will do himself an injury. He who mistakes the pleasure of gratifying his taste for that of satisfying his appetite becomes intemperate and is almost sure to lay the foundation for digestive troubles.

Since the appetite is the guide that most people follow each person should be particularly careful not to abuse it by improper habits. If he lives upon good, wholesome, plain food and drinks water, he may rely on his appetite; but if he pampers it with rich, highly seasoned foods, or if he injures it by overeating or by so-called alcoholic stimulants, he cannot depend upon it. If one leads a sedentary life, his appetite is likely to fail and he should arouse it by exercise rather than tempt it with rich, highly flavored dishes.

## VEGETARIANISM

Some people believe that a meat diet should be avoided and that a vegetable menu is conducive to better physical health. These people are called **vegetarians,** although they eat freely of eggs and drink milk. Most vegetables contain a very limited percentage of proteid; some, like cabbage, lettuce, tomatoes, beets, turnips, spinach and fruits, contain practically no proteids, and while they are of value in stimulating the digestive tract they do not furnish much nutriment.

The body is constantly demanding proteid, and while some vegetable foods, such as potatoes and cereals, contain large amounts of starch, they contain relatively smaller amounts of proteid than do meats. Experiment, too, has shown that the proteids of vegetables do not nourish the body as well as equal amounts of animal proteids. One could in time gather

a good deal of wheat by searching over the wheat fields and picking up the stray stalks left by the reapers; but it would be much simpler to take it from the wheat bins where large quantities are stored. Likewise enough proteid will be obtained if enough vegetable food is eaten; but this would usually involve the consumption of *too much starch.* It is better, therefore, to obtain proteid from the more concentrated foods. Some of the cereals, especially wheat, contain large quantities, as do beans and peas. Animal foods, as a whole, contain large amounts, which are more easily digested and of more value to the body than the proteids of vegetable foods.

Against the use of meats, on the other hand, several objections are urged. First is the claim that the frequent use of meat involves the eating of *too much proteid.* This is especially true of those who eat in restaurants and hotels, for with the menu of the restaurant before him almost every one will choose meat. It is believed that one of the primary causes of the kidney trouble prevalent among the American people is the excessive amounts of meat which are eaten in a country where that kind of food is comparatively cheap. Further it is urged that by means of animal foods certain injurious parasites such as tapeworms and trichinæ are sometimes introduced into the body; all these disastrous effects would be avoided if we refrained from eating meats.

Whatever one may think of the matter, vegetarianism is certainly a wholesome reaction against the food habits of certain classes of people who make meat the basis of every meal. There is, however, no good reason why meat should not, in proper proportion, form a limited part of our diet each day.

### INCIDENTAL ARTICLES OF FOOD

**Condiments.**—The *spices—pepper, cinnamon, allspice, mustard, nutmeg* etc.—*common table salt, the flavorings* used in foods, and the flavoring part of syrups used in drinks are all

condiments. None of these is really a food, since it contains no nourishment; but they are all useful in one of two ways: as agents for producing a pleasanter taste in some foods or as stimulants to provoke a more rapid flow of some of the digestive juices. Common table salt seems to be a necessity.

**Other Materials Needed.**—It will be seen from the figure on page 26 that besides the constituents of the three chief food substances the body contains a small but appreciable amount of other materials. Compounds of iron, sulfur, potassium and other elements, are all present in small amounts. One of these, the necessity of which is easily appreciated, is the mineral matter that forms the hard, resisting part of bones—**calcium phosphate,** or phosphate of lime, as it is sometimes called. Although one does not realize that he is consuming lime in his food, many foods contain it. It is present in eggs, as is shown by the fact that a chicken has bones when it is hatched. It is in wheat, also, and in meats in small amounts. In short, our common foods contain enough of this material to supply all the lime we need for bone formation and repair.

Sometimes a child whose bones are growing rapidly may eat so much sugar-containing food, such as cake, pastry and candy, that he gets too little of the more substantial foods and fails to obtain the proper material for his bones and teeth. This is occasionally shown by the rapid decay of the teeth and in permanently crooked bones in the legs, a condition called *rickets.* A more substantial diet of bread, eggs and meat would be advisable in such cases.

## COOKING

Everyone should know something about cooking. Cooking always means the application of heat in some form to a raw food. Sometimes it is done by placing the food in dry, hot air—*baking* or *roasting*; sometimes by putting the food in

boiling water—*boiling*; sometimes by submerging the material in hot or melted fat—*frying*. Heat has a variety of effects upon food and produces some decided chemical changes.

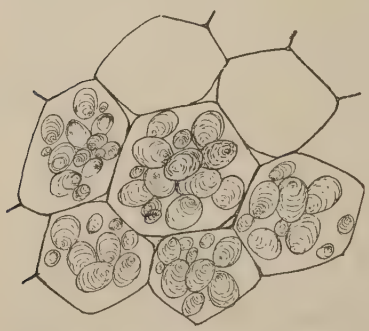


FIG. 23.—THE CELLS OF A POTATO
Showing the inclosed starch grains.

Few foods except milk and fruit are palatable in their natural state. Cooking food improves it in three different ways: (1) *in flavor*, (2) *in digestibility*, (3) *in safety as food*.

1. The change in flavor is very great, so great indeed, that in some cases our taste hardly recognizes the raw and the cooked food as being the same material. The "cultivated" tastes of the present day make people fastidious as to the flavors of foods. They seldom stop to question the nutritive value of a particular dish, but select foods with reference to their flavors, eating those that are palatable whether they are nutritious or not. An agreeable flavor is important, since it enables us more easily to digest our food.

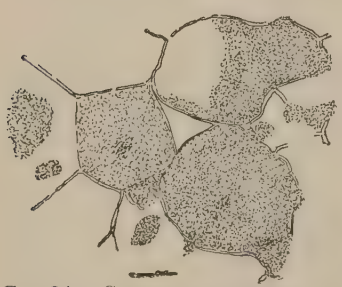


FIG. 24.—SHOWING HOW COOKING BURSTS THE STARCH-HOLDING CELLS

2. Exposure to heat and to the hot fluids in which foods are cooked does much toward softening food, "making it tender," so that later it readily falls to pieces under the action of digestive ferments and the mechanical grinding of the mouth and stomach. Vegetable foods, especially, need cooking. The walls of the plant cells resist digestive agents,

but the heat of cooking breaks them, setting free the starch granules which swell and burst under the influence of heat and are thus more thoroughly and easily acted upon by the saliva and other digestive juices; Figs. 23 and 24. Heat acts upon starch much as it does upon grains of corn. We can easily see that popped corn must be more readily digested than unpopped kernels. So far as ease of digestion is concerned the cooking of animal foods is not so important, since the connective tissue which holds the muscle fibres together is easily dissolved by the digestive juices. Indeed, most meats are more easily digested uncooked, since the proteid in them is coagulated by heat, and must be turned back again to a liquid condition before it can be absorbed. Frying, during which process the food becomes coated with fat, makes digestion difficult.

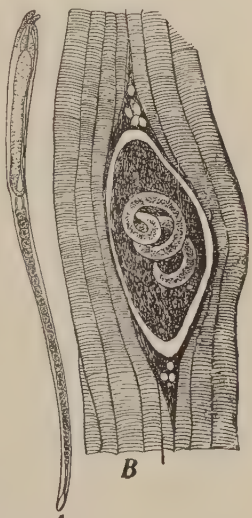



FIG. 25.— *A*, SINGLE TRICHINA. *B*, A BIT OF MUSCLE OF PORK Showing trichina between the fibres

3. There is another entirely sufficient reason for extreme care in the cooking of meats; this is the liability that parasites of some kind may be present in the meat fibres. Such parasites are found more commonly in pork than in any other kind of meat generally eaten. An apparently excellent piece of pork may contain in a single ounce as many as 85,000 of these little, round worms, *trichinae*; Fig. 25. If these are swallowed without being killed by thorough cooking, they wander out through the walls of the human food canal and take up their abode in the voluntary muscles of the body. As each female trichina may produce a thousand or more young, it is evident that a serious disease, *trichinosis*, may result.

The young of the *tapeworm* also may be concealed in meats, ready to attach themselves to the wall of the intestine as soon as liberated from the meat by the digestive juices. This animal never afterwards leaves the digestive tract, and its presence there is by no means fatal, although it sometimes attains great size and absorbs much of the nutrition which should go to feed its human host.

The practice of wholly or partially cooking milk is becoming more and more common. These processes are called *sterilizing and pasteurizing.* When milk is sterilized, it is heated at least to the temperature of boiling water, 212° F.; when it is pasteurized, it is not heated so much, usually to about 165° F. In either case the purpose is to destroy the microscopic germs which it contains. Milk, since it is such a nutritious food, furnishes an excellent abode for numerous bacteria. It is not uncommon to find 100,000 bacteria in a single drop of city milk. Most of these are quite harmless and may exist in the milk in great numbers without particularly injuring it. But sometimes, unfortunately, germs of serious diseases find their way into milk. Bacteria of *typhoid fever, tuberculosis, scarlet fever* and *diphtheria* are sometimes thus distributed. The germs that produce these diseases may easily be killed by heat, even by the moderate heat of 165° if it be rightly applied, and thus the milk may be rendered safe.

**Water.**—"Do you drink plenty of water every day?" is a question which a good physician often asks his patients; and in giving medicine he may prescribe a whole glass of water with a very small pill. It has been stated that three-quarters of the "blues," "gray days" and "east winds" which come over people, discouraging and depressing them, would be escaped if they would only drink a sufficient amount of cold water.

All living matter, i.e. all protoplasm, contains water; and while we cannot say that water is a food, we do know that it

is vitally necessary to us. No solid matter can be absorbed into the blood; everything must be dissolved and reduced to a thin liquid in order to pass through the walls of the intestine. The water necessary for this must be present, or absorption cannot take place.

If the food in the intestine is in a comparatively dry condition, it is moved along with difficulty, and indigestion may be the result. We are more likely to drink water too cold than to drink it in too great quantities; if very cold, it may chill the secreting surfaces, thus retarding their work and interfering with digestion. The amount of water given off through the lungs is about one pint per day, from the skin two pints, and through the kidneys, in the case of an average person, a little over three pints per day. Thus the demand for fresh water is constant.

As a result of the life processes, broken down products of body metabolism are continually produced. This material must be eliminated, and for this purpose it must be dissolved in the blood so as to be carried to the excreting organs. If one drinks too little water, the blood may become overcharged with such waste products, some of which are poisonous. These substances, when too abundant in the blood, may dull the nerve centers, giving one a disheartened feeling, and leaving him in poor mental condition for meeting the demands of life. By drinking plenty of water the body is kept constantly "flushed," as it were, and one's whole life is more vigorous and active. The Japanese soldiers have taught the world a lesson in methods of preserving health, and among other things have shown the beneficial results arising from drinking large quantities of pure water *without* "stimulants."

There is no good reason why we should not drink water freely during meals. The reason sometimes given for the contrary view—that water dilutes the saliva and gastric juice—has no great weight. Not only is water readily ab-

sorbed, but digestion proceeds more rapidly when the juices are somewhat diluted.

**Other Beverages.**—In America, the most commonly used beverages, other than water, are probably coffee, tea, cocoa and chocolate. Cocoa and chocolate are foods, since they contain some fatty material. Coffee and tea, on the other hand, can be considered only as stimulants. The active element in coffee is a substance called *caffein*; that in tea is called *thein*, the two being practically identical. The degree to which these affect different individuals is variable. As a rule they excite the nerve centers to greater activity. This may be of advantage in rare cases; but not when one is in bed, trying to sleep. After the use of these drinks becomes a habit, the nerve centers refuse to act well unless urged on by this "whip" and it is better to live in the strength of one's own natural vigor.

The "soft drinks" sold at soda fountains are made of water into which carbon dioxid gas has been pressed. Flavors in the form of syrups are added. Since carbon dioxid is really one of the waste products of the body, we might suppose that in our drink it would be harmful; but it is of real injury only when we breathe it. However, such drinks are no better than water; they are expensive and the syrups may impair digestion. Lemonade is used solely for its agreeable taste, although the sugar which is usually in it serves to a small degree as food. Some beverages are advertised as especially "good for the nerves," but this claim is largely a pretense used for the purpose of catching trade. If one finds any drink especially exhilarating, he is warranted in suspecting that it contains alcohol or a similar ingredient that produces temporary excitement.

**Alcohol.**—Alcohol must be considered here because it has so often been classed as a food, and has even been given the unfortunate misnomer, "liquid bread". Alcohol is derived from sugars by a process of fermentation. A large number

of vegetable products contain considerable starch which can easily be converted into sugar, and almost any of these may serve as a source of alcohol. The fermenting agent in all cases is yeast. This is sometimes intentionally added to the fermentable mass; but sometimes fermentation is caused simply by the action of the so-called wild yeasts, i. e. germs which exist everywhere in nature, and which may get into the material from the air, or more often from the skin of the fruit or other substance which furnishes the sugar. In wine and cider making, for instance, the yeasts are on the skins of the fruits, having dropped there from the air. The yeasts ferment the sugars, converting them into alcohol and carbon dioxid, and the fermented product is used to form the basis of alcoholic and fermented liquors.

Alcohol has a variety of undesirable effects upon the different functions of the body, and they are sometimes even disastrous, as will be pointed out from time to time in later pages. Here a word is in place concerning its possible food value.

Alcohol has no power to build up the body. It furnishes no tissue-building material and neither makes nor repairs any organ. Hence it does not nourish in the sense of building up the body. When taken in any except the smallest quantities, it is nearly all excreted from the body as alcohol; it is thus not utilized by the body and simply taxes the excreting organs.

A small amount of the alcohol taken, however, is not thus excreted but is consumed in the body, and the effect of this small portion must be considered. It is oxidized, and when alcohol is oxidized, it yields heat. This will occur if the oxidation takes place in a lamp and none the less surely if in the body; hence to a certain extent, alcohol is a source of heat. But only a small amount of our body heat can be derived from alcohol, not enough to constitute any considerable part of the supply needed for a day. Though a small quantity may fur-

nish a little heat, a larger amount of alcohol does not furnish more heat; it simply exerts a stronger and more clearly poisonous action. Moreover, the heat is not really utilized so efficiently as is the heat that comes from the oxidation of sugars; for one of the first effects of alcohol on the body is to enlarge the blood vessels in the skin, producing a flushed condition. This at once causes an increased loss of heat and in many cases, if not in all, more heat is lost in this way than is gained from the alcohol oxidized. The total result is, therefore, a loss rather than a gain of heat.

When we consider its further effects on the body, we soon find that it cannot properly be classed with the fuel foods like starch and sugar. Gunpowder if placed in a stove will yield plenty of heat, but notwithstanding this fact, it should certainly not be classed with fuels like wood and coal. So alcohol, even though it yields heat, has at the same time such undesirable effects upon the body as to destroy its value as a fuel food. The most exhaustive study has shown that alcohol is certainly a poison, interfering with the normal action of the cells of the body, and above all, with the normal action of the brain. This will be considered at length in a later chapter.

Nor is there any difference of opinion as to the wisest course to pursue in regard to the use of all forms of alcoholic drinks. They are all injurious, tending to throw the organs out of order, especially those of the nervous system, and they interfere with a healthful, vigorous life. Everyone who indulges in them at all is occasionally or constantly under the influence of their poisoning effect, and the only safe course is to avoid their use entirely.

Concerning these facts there is no question. The dispute as to whether alcohol should or should not be called a food has been due to a difference in opinion as to the definition of the word food and need not concern us. The accepted facts are clear and definite: alcohol is **primarily a cellular**

**and nerve poison.** If used in very small quantities it may yield heat and energy but whatever value it might have in this respect is usually quite nullified by its poisoning action. For this reason it cannot be classed with fatty and carbohydrate foods, and still less with proteid foods. The statement sometimes made that it is "liquid bread" is absolutely false and misleading.

## CHAPTER IV

## FERMENTATION AND GERM DISEASES

BEFORE food can be absorbed in the body it must be digested. We shall study the details of digestion later, but before taking them up, we must learn a little about the general process.

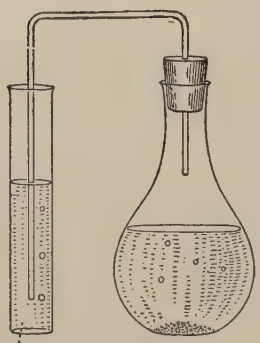



FIG. 26.—A FERMENTING SOLUTION

Showing the method of conducting carbon dioxid gas into lime water.

The changes in food during digestion belong to a type of activities known as **fermentation.** It is difficult to define the word fermentation, and we can best learn its meaning through illustrations.

### TYPES OF FERMENTATION

**Alcoholic Fermentation.**—If to a solution of sugar a little yeast is added, an active change soon begins. The sugar disintegrates and turns into alcohol and carbon dioxid gas. The sugar does not change spontaneously but only after the yeast is added, and the process continues until the sugar is used up. The microscope shows yeast to be a minute living plant; Fig. 27. While the sugar is fermenting, the yeast grows and multiplies, fermentation being a result of its growth. If the yeast is boiled, it is killed and can no longer excite fermentation. Since this yeast is a living plant it can properly be called an

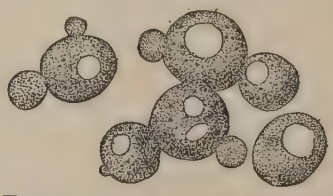


FIG. 27.—GROWING YEAST PLANTS

Showing the method of formation of buds on the sides of the cells.

organism, and we speak of this kind of fermentation as due to an organized ferment.

Later in this chapter, another group of organisms, the bacteria, are discussed and their intense fermentative powers are pointed out. Being organisms, they too would be termed organized ferments. While this designation is a convenient one in some ways, there is valid objection to its use. It is not the organisms themselves which are the ferments, but rather the substances which they produce. But usage has, as a rule, been that which is adopted in this text.

**Fermentation of Starch.**—The change of starch to sugar is a very simple one and is due to the union of starch with a little water, as follows:

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6$$
Starch Water Sugar

If we mix starch with water alone, we get no such result; but when we mix starch and water with saliva, the combination of starch with water begins, and sugar is formed. This may continue until the starch is all converted into sugar. If we boil the saliva it entirely loses this power; yet, if we study saliva with a microscope we find no living bodies in it corresponding to the yeast plant. Nevertheless, there is something in the saliva that provokes this change. That something can be separated from the saliva, and when so separated it appears as a white, structureless powder. It does not grow, multiply or increase like yeast during the fermentation processes. Since it is not alive it cannot be called an organism, and we speak of it as an **unorganized ferment**; it is more commonly called an **enzyme.** It is clearly a ferment but quite different from the yeast ferment. Moreover, when this enzyme converts starch into sugar, the starch and some water are used up, but the enzyme remains unaltered.

Further than this, we should note that a substance which has undergone one fermentative process and been broken up chemically into two or more different substances, may be still further subjected to changes by other ferments. As an illustration: starch changes into sugar; sugar may be broken by fermentation into alcohol and carbon dioxid; alcohol by fermentation will yield acetic acid (the acid of vinegar) and water; acetic acid by fermentation is resolved into carbon dioxid and water.

It is noticeable that the change is always from what is complex to things which are simpler; fermentation never produces the opposite result, *i. e.*, is never constructive. In other words, to use a chemical term, ferments are catalytic agents.

These two examples are illustrations of different types of fermentation, one produced by the growth of living, microscopic plants; the other by non-living enzymes.

While these fermenting agents are unlike in many respects, their activities agree in the following points, which are, therefore, characteristic of fermentations. 1. They are progressive chemical changes which take place in organic bodies. By "progressive" is meant that when once begun they continue until the fermenting body is used up or until something stops the action. 2. They never take place spontaneously, but are brought about by the addition to the fermentable body of substances called ferments. 3. They are stopped by the influence of heat, and by the presence of some chemicals. 4. The substance which starts fermentation does not appear to be used up in the process.

When a substance ferments, its nature is totally changed; alcohol and carbon dioxid are quite different from sugar, and sugar is unlike starch. Fermentation always forms new substances, and these new substances are sometimes good and sometimes bad in their effects. Fermentations may produce poisons from perfectly harmless substances. When starch is turned into sugar, the product is a useful food, but when sugar is turned into alcohol, the product is dangerous and

extremely harmful. When substances like meats are fermented (or putrefied) deadly poisons are sometimes produced. Hence, materials that were originally wholesome and harmless may, through fermentation, become unwholesome or even poisonous.

In the study of physiology we are concerned with both the organized and the unorganized types of ferments, but in consideration of digestion we have to do especially with the latter, or enzyme type. Several enzymes are formed in the body. Saliva contains one, which is called **ptyalin.** The gastric juice contains a second, called **pepsin** and another, called **rennet.** The pancreatic fluid probably contains three,—**trypsin, amylopsin** and **steapsin,** all of which contribute to the digestion of food. They are all normal products and are secreted by glands.

Organized ferments are living organisms, capable of growth and multiplication. Because of their microscopic size they are frequently called *microbes*; they are also called *germs*; but neither of these terms is very satisfactory, and it is better to call them by their proper names, **yeasts** and **bacteria.**

Living ferments, save when taken in large numbers, are invisible to the naked eye but are easily seen with a microscope. They differ from each other chiefly in their method of multiplication. Yeasts multiply by the formation of a small bud on the side of the plant; Fig. 27. The bud grows in size until finally it is as large as the original plant, when it may break away as a separate one. Bacteria, however, simply increase a little in length and then break in two in the middle; Fig. 28. Both bacteria and

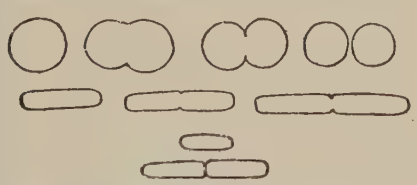


FIG. 28.—SHOWING THE METHOD OF MULTIPLICATION OF BACTERIA, BY SIMPLY ELONGATING AND THEN DIVIDING

yeasts bear very important relations to human health and happiness.

## YEASTS

Yeasts are abundant everywhere; they float in the air, are found in water and are in and on the ground. Such yeasts are sometimes called *wild yeasts*. Scientists have learned to cultivate them in laboratories, and they may be grown in great masses. A cake of compressed yeast is simply a cake of millions of these tiny plants, all alive and ready to grow if given proper food. These are called *cultivated yeasts*; but in reality the cultivated yeasts and the wild yeasts are the same kind of plants. When a cook wishes the dough "to rise," she puts a yeast cake in it, and the yeast, growing in the dough, ferments sugar in the starch of the flour, producing bubbles of gas, which make the dough

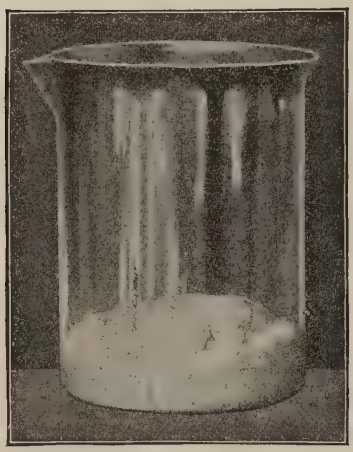


FIG. 29—RECENTLY MIXED DOUGH, INOCULATED WITH YEAST, BUT BEFORE THE YEAST HAS GROWN (Conn, *Bacteria, Yeasts and Molds*).

FIG. 30.—THE SAME DOUGH AFTER YEAST HAS GROWN AND CAUSED THE DOUGH TO SWELL BY THE ACCUMULATION OF GAS (Conn, *Bacteria, Yeasts and Molds*).

"swell"; Figs 29 and 30. Alcohol also is produced, but passes off when the bread is baked. The use of baking soda in preparing food materials produces a lightness due to bubbles also; but only the water in the mass is affected by its presence.

When a brewer makes beer, he makes a solution from certain grains, containing starch which is changed into sugar, and plants yeast in it. The yeast grows and destroys the sugar, producing alcohol and carbonic acid gas. In the making of cider or wine, when the sweet juice from apples or grapes is squeezed out and placed in barrels, the wild yeasts from the air grow in it, producing the same changes.

## BACTERIA

Bacteria are more abundant than yeasts and are even smaller (Fig. 31); they are so small that sometimes 50,000 of them, side by side, would reach only an inch. But small as they are, they play a very important part in our lives and in the world. It may seem strange that organisms as minute as these can have an appreciable effect. A single one, to be sure, could do very little; but bacteria have such wonderful powers of reproduction that they can accomplish much. So fast do they multiply that, under favorable conditions, in twenty-four hours a single one may have seventeen million offspring, and in another twenty-four hours each of the first seventeen millions may have seventeen million more. Most people think of bacteria, germs or microbes as our deadly foes. While this is partly true, it is likewise true that they are our friends. Their distribution in the world shows clearly enough that they

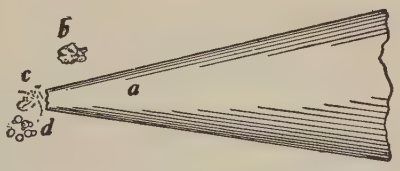



FIG. 31.—SHOWING THE COMPARATIVE SIZES OF THE POINT OF THE FINEST CAMBRIC NEEDLE (*a*), A PARTICLE OF DUST (*b*), BACTERIA (*c*), AND YEASTS (*d*)

cannot always be mischievous. They are found in the soil under our feet, in the air we breathe, in the water and milk we drink, in much of the food we eat; Fig. 32. They are on our clothing, on our skin, in our mouths and stomachs (Fig. 33); there are countless millions in the intestine of every healthy person.

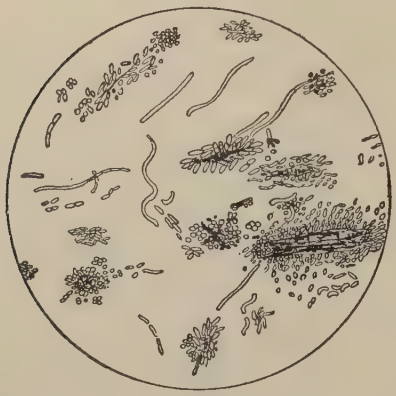


FIG. 32.—A BIT OF DECAYING MEAT
Highly magnified, showing the bacteria that cause its decay.

**Beneficial Bacteria.**—Although bacteria are very small and are very simple organisms, there are many different kinds known; and while some are injurious, the great majority are harmless and some are even beneficial. One of the ways in which they are of value to us is through their power of causing all sorts of putrefaction and decay. This may not seem to be either useful or desirable. Putrefying and decaying material is disagreeable and its odor is unpleasant, but the process is really one of great value, for it is nature's way of destroying the dead bodies of animals and plants, which would otherwise accumulate, covering the ground and filling the streams. The bacteria of the air, ground and water attack and consume all such materials. As they consume them they produce gases which give the unpleasant odors to the

FIG. 33.—BACTERIA FROM A HEALTHY MOUTH, MAGNIFIED

decaying bodies. Nearly all kinds of decay are thus produced by bacteria or closely allied organisms. The putrefaction of meats and eggs, the souring of bread and milk, and hosts of other processes by which food is spoiled are instances of bacterial action; Fig. 34.

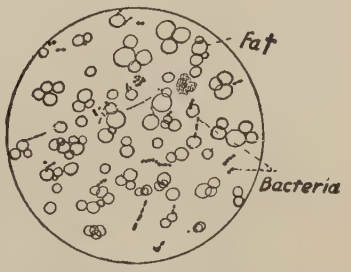



FIG. 34.—A DROP OF MILK UNDER THE MICROSCOPE
Showing fat drops and bacteria.

Since the spoiling of food is produced by bacteria, it follows that the preservation of food for an indefinite length of time is possible if bacteria can be kept from it. This is not an easy matter, however, because of the wide distribution of these plants. They are sure to get into the foods in spite of all ordinary caution. But many foods may be protected from them by the process of **canning**. In canning, foods are first subjected to a heat (commonly boiling) sufficient to kill any bacteria in them, and then are sealed up in jars or cans so tightly that no air or bacteria can reach them. If this is done thoroughly and carefully, the food will keep indefinitely. At any time afterward the cans may be opened with the certainty that the food will be found in good condition. The discovery of the methods of canning has been of extreme value, for it made it possible to preserve for winter use vast quantities of food grown in the summer, which would otherwise spoil before they could be consumed.

When such materials are decomposed by bacteria the products that come from them pass into the soil and air in a form which can be used by subsequent generations of plants. In this way soil is kept fertile, and we can depend upon getting, year after year, abundant harvests. Were it not for the action of bacteria the soil would soon cease to yield crops, and we should eventually starve.

The flavors of butter and, in part, of cheese are due to bacteria. Butter makers have learned that they can make better butter if they put bacteria into the cream out of which butter is to be made. They plant bacteria in cream, much as cooks plant yeast in bread for bread raising, or farmers plant grass in the fields. We must, therefore, look on bacteria in many cases as our best friends. When we remember that we have always carried millions of them in our mouths, and still have enjoyed good health, we must not be alarmed if we are told that there are bacteria in water, or milk, or in the air we breathe.

**Harmful Bacteria.**—Unfortunately some kinds of harmful bacteria live and grow in the various organs of our bodies. It is easy to understand that when these minute parasites are growing in great numbers in different parts of the body, they may produce trouble. Such troubles are called diseases, and to the bacteria which cause them is given the name of **disease germs,** or **pathogenic bacteria.**

Not all kinds of disease are produced by bacteria. Some, like malaria, are caused by tiny animals. The causes of some diseases have not yet been determined, but probably many are brought about independently of bacteria or parasitic animals. Nevertheless, most of the common illnesses are produced by them, and none of the diseases caused by bacteria ever make their appearance unless the germs that cause them first get into the body and find opportunities for growth there. Any disease caused by living germs is called **infectious.**

In most of these diseases the bacteria, after having developed in the body for a while, begin to be given off in some way. Sometimes this takes place through the mouth, sometimes through the excreta, sometimes through the breath, sometimes through special discharges of the skin. When bacteria are thus given off from the body of a sick person, they are alive and active, and are generally in condition to enter the body of another individual and produce the same trouble in him.

Hence one person can easily take a disease from another. Such diseases are called **contagious.**

All contagious diseases such as *diphtheria, typhoid fever, tuberculosis, measles, whooping cough, scarlet fever and small-pox* seem to be produced by living organisms, minute in size but capable of living a parasitic life in the body, and passing readily from one person to another. The germs causing them are not always of that class called bacteria, but they are always minute, always parasitic and may all be properly classed as disease germs. The methods by which these germs pass from the patient to the healthy individual are various. The bacteria themselves are not capable of any considerable amount of motion, and are never able, of themselves, to travel from person to person. They must be carried, and the various kinds are carried by different means. Some are carried in the air, some by water and some by insects.

Some diseases are very contagious, by which we mean that they are very easily " caught "; and others are slightly contagious. This really refers to the ease with which the germs can be carried from person to person and taken into the body. In cases where the germs must pass into the water and be subsequently drunk before they can enter the body of another individual, it is evident that the liability of contagion is less than in the cases where they simply pass into the air and are breathed in by a second individual. All such diseases are *infectious,* but not all are necessarily *contagious.* A study of methods of transmission will give us valuable information as to ways of preventing contagion.

## IMMUNITY

Almost all kinds of bacteria are harmless even if they do get into our bodies. This means that they are not able to multiply in the body so extensively as to produce trouble. We are **immune** against them. Moreover, certain kinds of bacteria can grow in some of the lower animals and produce

trouble there, though the same sort cannot injure man. Further, it is well known that some people "catch" diseases more easily than others. Some people, indeed, although again and again exposed to diseases, do not take them, while others under the same conditions take them easily enough.

Lastly, in the case of some diseases, such as scarlet fever, mumps and whooping cough, if a person has them once and recovers, he is not likely to have them again even though exposed to them. Such persons are immune against a second attack of these diseases. *Immunity is a condition which enables a person to resist diseases when exposed to them.* The greater one's power to withstand diseases, the more secure is his health.

There are various methods by which immunity can be produced; one factor only need be mentioned here.

Resisting power varies with the physical condition of the person. One in good health, with strong vitality, is less liable to take the germ diseases than one who is less robust and vigorous. Out-of-door life, and the eating of wholesome foods are, thus, among our greatest safeguards against them. Especially has it been shown that alcohol tends to lower this power of resistance, and persons addicted to the use of alcoholic beverages are more liable to yield to the attack of infectious diseases than are those who refrain from their use. The reasons for this are not wholly known. It is certain that alcohol is primarily a poison, acting directly upon the living cells so as to interfere with their normal functions. Resistance to disease is dependent upon the activities of the cells, and it is natural to conclude that if alcohol acts in any degree as a cell poison it will interfere with this resisting power. At all events, the facts are certain; and the more frequent the use of alcohol, the less is one's power of resistance to harmful bacteria.

## STERILIZATION AND DISINFECTION

In connection with bacteria and germ diseases, we frequently hear the terms, **sterilization** and **disinfection.** To disinfect means to treat a thing in such a manner as to destroy any micro-organisms that might produce infection or disease. If there were harmful bacteria in water and we could kill them without injuring the water, evidently the danger in drinking it would be removed. If a room has been occupied for some time by persons suffering with a germ disease, bacteria may be distributed through the room, on the floor, ceilings, curtains, etc., and other people who come to live in the room later will be likely to become infected. If we can treat the room in such a way as to destroy the bacteria, it may be rendered safe. This we call disinfection. To sterilize any object means to kill all organisms whether disease-producing or not.

The simplest method of sterilizing is by the use of heat. All bacteria are killed by sufficient heat, and nearly all that are liable to produce disease in man are killed by the heat of boiling water. Therefore anything that can be boiled, like water or milk, or anything that can be treated in boiling water, like towels or sheets, can be easily sterilized by this means. Water and milk are frequently treated in this way when there is any suspicion of their infection. When one is uncertain as to how to sterilize or disinfect suspected articles it is wisest to follow the advice of health officers, whose duty it is to know these methods and their practical applications.

## CHAPTER V

## DIGESTION OF FOOD: THE MOUTH AND THROAT

In their original condition most of our foods are of no more value to the body than are the trees of the forest or the stones of the quarry to the builder, good as raw material, but not immediately available. Before they can be taken into the blood they must be softened, ground up into small bits and at least partially dissolved into liquid form. This process is a long one beginning, perhaps, when the food is in the hands of the butcher or miller, and carried further, by some process of cooking. The chief part of this preparation, however, is performed by the alimentary canal, whose main function is to grind and dissolve the food masses into readiness for absorption. This process of disintegration is partly mechanical and partly chemical, and we call it **digestion.** The digestive canal is, in a sense, a chemical laboratory.

FIG. 35.—SCALE-LIKE CELLS FROM THE LINING OF THE MOUTH

### THE MOUTH

The preparation of food for absorption begins in the mouth. The whole mouth cavity is lined with a smooth, moist membrane, consisting of cells (Fig. 35), which secrete a transparent liquid somewhat thicker than water and called **mucus.** Mucus is of no value as a factor in digestion, but it keeps the lining membranes soft and flexible, and lubricates dry foods

so that they can be pushed back toward the throat more easily. This living mucous membrane and the outer skin of the body come together at the lips. They are much alike in structure save that the blood vessels come nearer the surface in the mucous membrane and make it look redder.

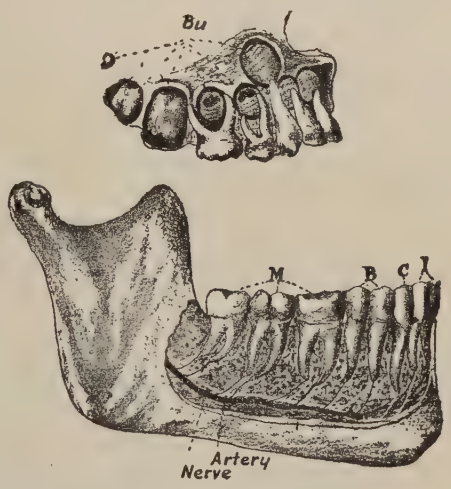



FIG. 36.—SHOWING THE UPPER JAW OF A CHILD AND THE LOWER JAW OF AN ADULT

In the upper figure *Bu* indicates the buds of the permanent teeth nearly ready to push out the first set, or milk teeth.

**The Teeth.**—Back of the lips, which aid slightly in holding and directing the food, are the teeth. These, by cutting, tearing and grinding the food, prepare it for digestion. Their shapes are admirably adapted for this work, which is called **mastication.**

The teeth of each side of each jaw, beginning at the middle in front, comprise two incisors, one canine, two bicuspids and three molars, or grinders. The **incisors** (Fig. 36 *I*) with chisel edges are used almost exclusively for cutting pieces from large morsels; in chewing they come into action very little. The **canines** (Fig. 36 *C*), named from their similarity to the tearing, tusk-like teeth of dogs, are of no great service to civilized man, who, though he may eat fruits without first cutting them, usually cuts his other foods with knife and fork. The **bicuspids** (Fig. 36 *B*), so called from the two prominences, or cusps, on their free ends, are of use partly for tearing, and partly for grinding. The **molars** (Fig. 36 *M*), or heavy, many-cusped "back teeth," are solely for grinding. Their

position, far back near the hinge of the lower jaw, gives great leverage; and being farthest from the mouth opening and nearest the largest part of the cheek, room for their grinding function is insured. The remarkable fitness of each structure for its work is a striking fact which may be noticed in all parts of the body. All of these are permanent teeth. All except the molars are preceded in childhood by baby teeth which are lost in early years. Permanent teeth may appear as early as six years of age, and since this is so, particular pains should be taken that they are properly cared for from the time of their first "cutting through."

If a tooth is cut open, it proves to be made of four kinds of material. The outside layer (see Fig. 37), an extremely hard deposit of calcium phosphate, is called the **enamel.** This is thickest on the exposed surface of the tooth, or crown, and diminishes until, as the tooth enters the gum, it gives way entirely to a softer substance, the **cement.** This cement covers the roots and connects the teeth firmly with their sockets in the jaw bone. It is this substance which yields when a tooth is extracted.

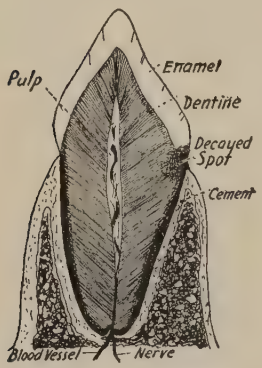



FIG. 37.—A SECTION THROUGH A TOOTH

Inside the enamel and cement is a uniform layer, the **dentine.** This, too, is calcium phosphate in composition, but is less hard than the enamel. Inside the dentine is a space occupying the central part of the tooth, and extending down into the tips of the roots. This central space is occupied by a soft, pasty mass, like the marrow of a bone, filled with fatty and connective tissues, blood vessels and nerves. These vessels and nerves enter the tips of the roots, the former bringing

nutritive materials for the tooth, the latter regulating the use of these materials; Figs. 36 and 37.

**Care of the Teeth.**—Cleaning the teeth may seem to be unnecessary, or merely a matter of good form; but this is a wrong idea. In spite of the hard nature of the teeth, they are very liable to decay, as almost everyone knows to his misfortune. This decay is brought about by circumstances which we can in great measure prevent if we understand them. It is caused in part by the bacteria in the mouth. These are not able to affect the uninjured teeth though they can readily attack the softer foods that may lodge in or between them. If, after eating, one chances to leave some of the food in the crevices between the teeth, the bacteria at once begin to feed upon it. The mouth is warm and moist and furnishes the very best possible conditions for bacterial growth. In these particles of food, therefore, bacteria flourish and, after a time, turn them sour in much the same way that they turn milk sour. The sourness is due to the production of an acid, which, although not formed in very large amounts, always appears if food is left between the teeth. Upon the hard substance of the teeth this acid acts at once, dissolving the lime in such a way as to produce soft spots or even cavities. Upon the hard enamel the acid acts only with difficulty, but if this is cracked or broken the acid acts easily upon the softer dentine within. As soon as these weak spots appear the teeth decay rapidly; Fig. 37. Since our permanent teeth do not grow and are never repaired or replaced by nature, it is very important that they be kept in good condition.

It is becoming more and more certain that material from decayed teeth, or from pus cavities in or above their roots, may cause very unexpected and serious results, e. g. nervousness, epilepsy, indigestion, blindness, or even insanity. "Mouth cleanliness" is of the greatest importance.

What is the use of toothache? Though unpleasant, it certainly

tells one that he is not treating his teeth properly since a toothache generally means decay. If one avoids injuring the enamel with hard substances, and if he does not allow food to remain between the teeth for the bacteria to act upon, he can thus check the process of decay. Carbohydrate foods are most liable to be turned acid by bacteria, and hence bits of cracker or bread are among the worst materials to leave lodged in the mouth.

When a tooth begins to decay, the dentist removes the decaying portion; he then closes the opening with gold or silver or some other hard material. It is extremely important to have a cavity attended to when it is very small so as to save the tooth; hence the teeth should be examined by a dentist at least twice a year. This is not only necessary as a means to uniform health, but, contrary to the belief of some, is much the most economical custom for every one.

FIG. 38.—THE SURFACE OF THE TONGUE

**The Tongue.**—The tongue is a mass of muscles whose fibres can move it in different ways, either guiding the food in the process of chewing or carrying the food back toward the gullet. On the upper surfaces of this organ are numerous minute projections, or **papillæ**; Fig. 38. Everyone has noticed the very rough tongues of dogs and cats. On the human tongue are three kinds of papillæ. The largest, called the **circumvallate,** are few in number and at the very back of the tongue; Fig. 38. These papillæ are short and blunt in

structure, growing up from shallow pits in the tongue's surface. More numerous than these and scattered over the remainder of the tongue are two types, the **filiform** and the **fungiform** papillæ. As the terms indicate, the former are slender and thread-like; the latter are short, pillar-like growths. In the tissues of the circumvallate and fungiform papillæ are located the organs of taste, the so-called **taste buds.** The cells making up these buds are elongate, arranged in a more or less spherical mass. The cells in the middle of this mass come close to the surface and are affected by the food which touches them; Fig. 39. From them the stimulus passes through nerves to the brain.

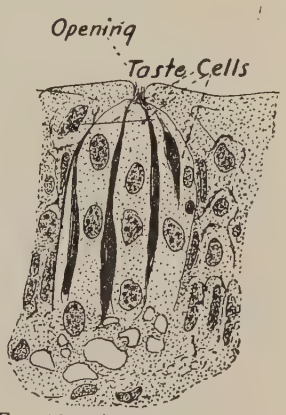



FIG. 39.—A TASTE BUD FROM THE TONGUE
Highly magnified, showing the taste cells.

There is a kind of taste geography mapped out on the tongue's surface. Bitter tastes are noticed at the back of the tongue, acid on the sides, salt and sweet toward the front. None of these tastes can be perceived if the tongue be wiped dry. In other words, all material to be tasted must be in solution.[1] Electric stimuli applied to the tongue produce the same impression as dissolved foods. Thus arises the popular contention that electricity is sweet, for the wires are usually applied to that portion in which the sweet-perceiving nerve endings are located.

**The Palate.**—The roof of the mouth toward the front is called the **hard palate** and contains a bony partition between the mouth and nose chambers. This bony partition, however, soon ends, and the palate continues backward toward the throat as a soft membrane; Fig. 40. This **soft palate** extends

[1] Students should prove these statements by experiments at home.

to the place where the nose and mouth cavities come together to form the throat or pharynx. From the back edges of the soft palate, just in the middle, hangs down the **uvula,** a vertically placed piece of connective tissue and muscle, half an inch long and about a quarter of an inch thick. The uvula sometimes becomes swollen and elongated until it hangs down on the tongue and even into the throat. It then produces a slight tickling which excites a cough. A physician sometimes cures diseases of the throat by removing a piece of the uvula.

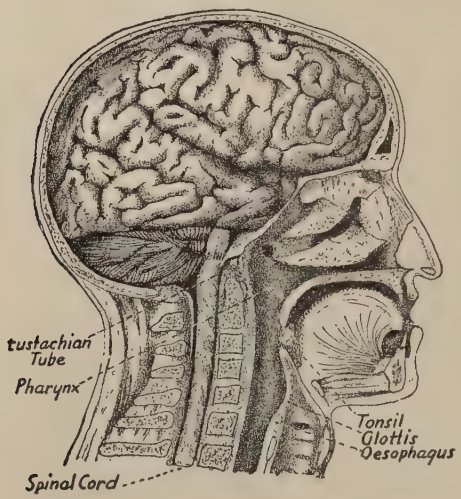



FIG. 40.—A SECTION THROUGH THE HEAD
Showing a surface view of the brain, and the mouth and nasal cavities.

In these days of hurry and stress, too much emphasis cannot be placed on the necessity of thoroughly chewing the food. If swallowed in large pieces, only the surface of these will be easily dissolved.

## DIGESTION IN THE MOUTH

While food is being crushed into small pieces by the teeth, it is mixed with the liquids in the mouth until thoroughly moist. The membranes of the mouth are kept wet by a mucous fluid that exudes from their surfaces and is mixed with the food, upon which it really has no special effect. As soon as the food enters the mouth and indeed, sometimes before—for the mere sight of food or

even the thought of it produces the same effect—a watery liquid, the **saliva,** begins to be poured into the mouth. This comes from three pairs of **salivary glands.** 1. The **parotid,** just below and in front of each ear, with long ducts opening through the sides of the mouth opposite the second molar teeth. 2. The **sublingual,** beneath the tongue, with numerous separate ducts. 3. The **submaxillary,** beneath the tongue, on each side, near the angle of the jaw; Fig. 41. The ducts of these last open under the tongue, on each side of the middle, toward the front, on slight elevations.

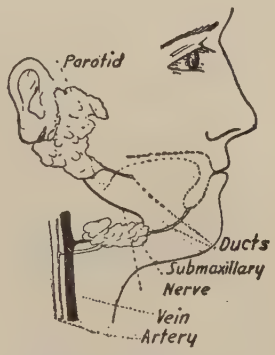



FIG. 41.—DIAGRAM
Showing the positions of the parotid and submaxillary glands.

These salivary glands are compact masses of varying sizes. The parotids are flat and of almost the same area as the ear; the submaxillaries are about the size of a walnut. Under a microscope they are found to consist of many minute cavities. If one imagines a cluster of extremely small grapes, which are hollow, and discharge sap into their stems, he will get a good picture of the structure of such a gland; Fig. 42. Each spherical cavity (or each grape in the illustration) is called an **alveolus,** and each has its walls made of cells. The cells extract from the blood material out of which they make saliva; this they pour into a little duct which drains the alveolus. Each duct joins others from other alveoli, and all finally unite to form a single duct which carries the secretion into the mouth. These little clusters of hollow sacs are microscopic, very numerous, and all bound together into a compact mass. Several other glands in the body are constructed on the same plan, and this pattern is called **racemose** from a Latin word that means "full of clusters."

The salivary glands really receive stimuli from the brain. The taste of food starts a nerve impulse that goes to the brain; there certain nerve centers are excited and from them another impulse passes to the salivary glands, causing them to secrete saliva. This passage of the impulse from the brain to the glands is an unconscious one, and we certainly do not secrete saliva by any volition of our own. Such an action is called a **reflex action.**

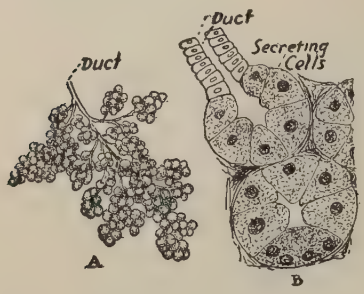



FIG. 42.—SHOWING THE STRUCTURE OF A SALIVARY GLAND

*A*, moderately magnified and represented as less compact than in reality. *B*, two alveoli, highly magnified and showing the connection with the duct.

Saliva is more than 99% water. This moistens the food and makes it easy to swallow. Indeed, this is one of the most important functions of saliva. One cannot swallow a dry cracker until he has thoroughly wet it with saliva or water. When people are much frightened their salivary glands sometimes refuse to secrete and at such times they find it difficult or impossible to swallow.

While this is a very important function, saliva has also a digestive action on the food. This is due to an enzyme called **ptyalin,** present only in very minute quantity, but having a powerful effect on starch, which it converts into sugar. This change is absolutely necessary, since starch unchanged cannot be absorbed from the digestive tract and hence cannot be used in the body. The conversion of starch into sugar, as we have already noticed, is brought about by the addition of water to starch. (See page 63.) But this combination will not occur except under the influence of some outside agent such as ptyalin. Sugar is a substance that is easily absorbed through the intestine while starch cannot be absorbed at all. Hence this change from starch into sugar is true **digestion.**

In eating, food is usually kept for so short a time in the mouth, is so imperfectly chewed and broken up that the ptyalin solution acts upon only a small portion of the starch. Saliva does not at all affect other foods, i.e. fats or proteids. In its chemical reaction it is slightly alkaline, due to traces of inorganic salts. Ptyalin will not act at all if the food mass is acid, as when it is mixed with vinegar.

### THE THROAT

**The Pharynx.**—Back of the mouth and partly shut off from it is a considerable cavity called the **pharynx,** or **throat,** through which food must go before it reaches the gullet; Fig. 40. In a person of average size this cavity is about four and a half inches in length and of varying width.

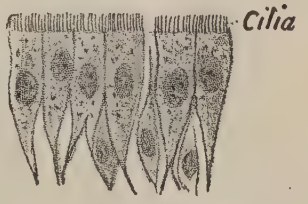



FIG. 43.—CILIATED CELLS THAT LINE THE PHARYNX

It is partly shut off from the mouth by the tongue below, by the soft palate and uvula above, and by the **pillars of the fauces** at the sides. These last are vertically placed folds of tissue which can be easily seen by opening the mouth widely before a mirror. They are somewhat like thick curtains hanging down at the sides of the opening into the throat.

**The Tonsils.**—To one who thinks that there is a use for everything in the world, it is interesting to find that there are several structures in the human body which are apparently of no value. Among these are the **tonsils,** which are frequently removed by a slight surgical operation. These growths are located on each side of the passage from the mouth to the throat, one between each pair of the pillars of fauces; Fig. 40. They vary much in size, though in most cases they are about as large as half a walnut. From their position they are much exposed to currents of air taken in

through the nose or mouth, and thus easily become inflamed by excessive cold, or by foreign particles in the air.

There are other openings into the pharynx besides that from the mouth; of these, two open from the nose just above the soft palate, near the mid-line. At this upper end where the nasal passages enter, the pharynx cavity is not very large and is roofed over by the lower bone of the brain box, covered by a soft membrane. Into this part of the pharynx project innumerable hair-like structures, called **cilia**; Fig. 43. These cilia are minute, transparent filaments which have the power of lashing to and fro and creating a current in the mucus on the surface of the cells. Particles of dust may thus be moved along, and tears, which run down into the nose canals, may also be hurried to the pharynx, where one becomes conscious of the liquid and spits it from the mouth or swallows it.

These dust particles in the air are generally covered with bacteria; and since the tonsils are deeply wrinkled, these bacteria easily lodge in the crevices and provoke inflammation. It has even been proven that 80% of diseased tonsils harbor the type of bacteria which causes tuberculosis, and may thus act as an entrance point for this most serious malady.

In the upper part of the pharynx cavity on each side is a minute opening through which a bristle can be thrust into a canal leading to the ear. These small passages are called the Eustachian tubes, and have much to do with hearing; Fig. 40.

If one closes the nose passages by holding the nose between the fingers, and then swallows, the noise in the ears shows that a passage exists between them and the throat. When the pharynx wall is sore and swollen (pharyngitis), this canal may become closed and a disagreeable noise be constantly heard.

At the lower end of the pharynx are two comparatively large openings. The front one is the **glottis**, which is the upper end of the windpipe, and leads to the lungs; the one behind that is in the **gullet**, or **oesophagus** opening, and leads to the stomach. It is evident, then, that all food which leaves the

mouth on the way to the stomach must pass over the upper end of the windpipe.

There are, therefore, seven openings into, or out of the pharynx, all of which may be closed. The large passage from the mouth may be closed by the tongue, the soft palate and the pillars of fauces, all of which contain muscles; the Eustachian tubes can be closed by muscles going around the tubes and by the pressure of surrounding tissues; the glottis, by a lid-like door, the **epiglottis,** which drops back over the opening when anything is swallowed; and the œsophagus may be closed through the contraction of muscles which pass circularly around it. The entrance from the nose passages is less perfectly shut off than the others and less often; but it can be closed by the raising of the curtain-like soft palate and the general contraction of the muscles in the upper part of the pharynx. One or the other of these openings may be closed according to whether food or air is passing through the cavity.

### DISEASES OF THE MOUTH AND THROAT

**Tonsilitis.**—We have already noticed that the mouth usually contains microscopic germs, called bacteria. Ordinarily these do no harm, but occasionally bacteria of a more malignant type get into the mouth and produce trouble. They sometimes attack the tonsils or the roof and walls of the mouth and throat, causing inflammation; the result is first noticed as a **sore throat,** which may merely have an appearance of redness that soon disappears. If the throat is covered with white patches, however, and the tonsils are swollen and painful, the trouble is called **tonsilitis**; Fig. 44. This is accompanied by fever and a general feeling of illness; but it is not likely to be serious, and with proper treatment will soon pass away. If the inflammation becomes still greater, and the surrounding tissues are distended with pus,

FIG. 44.—BACTERIA (STREPTOCOCCI) Found in cases of tonsilitis.

## CHAPTER VI

## DIGESTION OF FOOD: THE ŒSOPHAGUS AND STOMACH

Connecting the pharynx and the stomach cavities is a tube about ten inches in length called the **œsophagus.** This tube is lined throughout by an epithelium secreting mucus, and for this reason it offers little resistance to the swallowing of food.

**Swallowing.**—After food has been masticated and moistened by the saliva it is rolled up by the tongue into a smooth, moist mass. The tongue is then pushed up against the roof of the mouth, first at its tip, and then moved backwards; the food ball, being moist, slips along easily and is pushed through the opening into the throat. Up to this point the process of eating has been under one's control and could have been stopped at any moment; but as soon as food goes into the throat it passes beyond voluntary management. If one should discover at this moment that the food contained poison he could not refrain from swallowing it, for from this point the action is *involuntary*, i.e. cannot be governed by one's will power.

"How can a man standing on his head drink water, or a cow drink out of a brook when her head is so much lower than her stomach?" This question is easily answered as soon as we understand the action of the œsophagus. Two coats of muscle are found in the wall of the tube; next to the lining is a layer of muscle going around it, and outside this is a layer running lengthwise. By the combined action of these a "swallow," or bolus, of food is pushed downward, the muscles in front of the food mass continually letting the

passage open up, while those behind the mass contract and thus push it along. The result is much the same as when one forces a slippery ball through a rubber tube by squeezing the tube between the thumb and finger behind the ball. This action on the part of the muscles would, of course, carry food along the tube, no matter what the position of the body. Even water does not run down the gullet; it is pushed down, gravity having little or nothing to do with the process. This peculiar method of movement, called peristalsis, occurs throughout the entire alimentary canal. In man, a wave passes from the pharynx to the stomach in about six seconds.

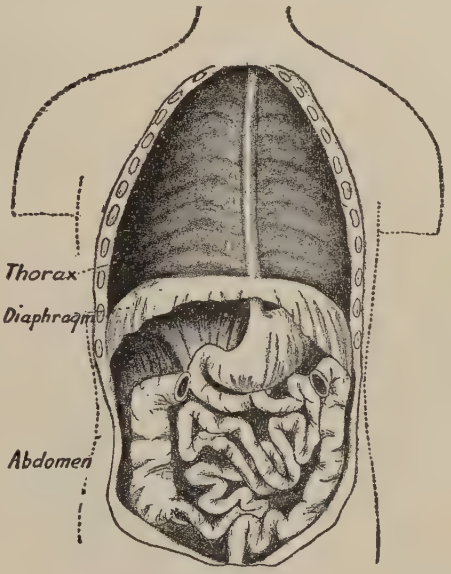



FIG. 46.—SHOWING THE BODY CAVITY DIVIDED BY THE DIAPHRAGM INTO THORAX AND ABDOMEN

### BODY CAVITY AND ITS SUB-DIVISIONS

All the space inside the ribs and the body wall, from the hips to the shoulders, is called the **body cavity.** This is not all in one large space, but is divided into an upper and a lower part by a horizontal partition, called the **diaphragm**; Fig. 46. At its center this is a thin sheet of tendinous material from the edges of which muscles radiate to the body wall; it extends across the body cavity between the ribs, backbone

and breast-bone, about one-third of the way down from the shoulders; see Fig. 46. The upper and smaller cavity is called the **chest,** or **thorax**, and its principal contents are the heart and lungs. The lower, larger space is the **abdominal cavity,** which contains the stomach and intestine, the large glands connected with them, and the spleen, kidneys and bladder.

There are irregular crevices and spaces between these organs, but these are perfectly filled with the body cavity fluid (*coelomic fluid*).

Nearly all these organs have some muscular tissue in their walls and are continually going through movements; or if they are themselves quiet, they are being constantly rubbed against by neighboring organs which are in motion. This would result in a large amount of friction and irritation, if it were not for the secretions of the **serous membrane,** which forms a delicate lining to both the thoracic and abdominal cavities. This lining in the thoracic cavity is called the **pleura**; that of the abdominal cavity is known as the **peritoneum**; Fig. 47. Along certain lines, this lining is raised into folds which hang out into the cavities and in these folds the organs are held. One particular fold of the peritoneum, called the **mesentery,** is especially large and holds the small intestine. This complex lining is composed of one-celled glands, constantly secreting a colorless fluid which allows the organs to glide easily over one another or against the walls of the cavity.

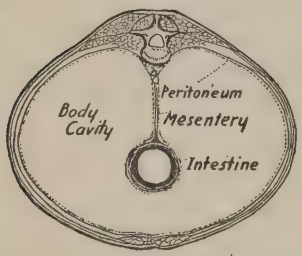



FIG. 47.—DIAGRAMMATIC SECTION ACROSS THE ABDOMEN
Showing the relation of the peritoneum and mesentery.

### THE STOMACH

The œsophagus extends down through the thorax as a nearly straight tube, passing through the diaphragm, after

which it enlarges into a good sized organ, the **stomach**, lying a little to the left of the middle line; Fig. 46. The stomach is pear-shaped and lies with the small end pointing obliquely downward, and to the right. When moderately full it is about ten inches long, by four wide and deep, and holds about three pints. The entrance of the œsophagus is on the upper side, about the middle of its length, and is commonly closed by a muscular ring, the **cardiac valve**; Fig. 48. This prevents the food from going up the œsophagus again, while the stomach is contracting about it. Sometimes, when there is too much food in the stomach, or when the food does not digest well, this valve opens and a reversal of the muscular action forces the food back through the œsophagus to the mouth. This is **vomiting** and occurs most frequently in babies, in which case the cause is, generally, too much food. With adults, vomiting and nausea usually occur only when the stomach is disturbed by food which does not properly digest.

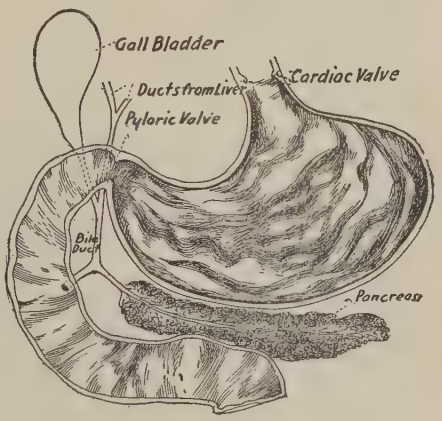



FIG. 48.—DIAGRAM OF THE STOMACH AND INTESTINE LAID OPEN

Showing the relation of ducts of liver and pancreas to one another and to intestine.

From the small end of the stomach, called the pyloric end, starts the first section of the intestine, the opening into it being guarded by the strong, circular, muscular **pyloric valve**; Fig. 48.

The cavity of the human stomach is one continuous space, though in some lower animals which "chew the cud," as we say, there are four divisions in it; Fig. 49. In the camel,

too, numbers of sac-like outgrowths from the stomach are provided, in the cavities of which water is stored to be used when the animal needs it. On the exterior of the human stomach is a moist covering which is, in reality, continuous with the mesentery in which the intestine is swung. Inside this are three sets of **muscle fibres,** longitudinal, circular and oblique, and separated from the lining of the stomach by a thin layer of **fat,** the function of which cannot be definitely stated.

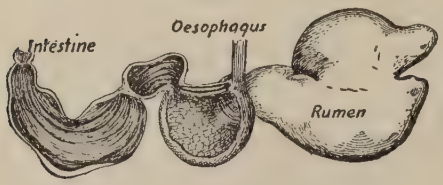



FIG. 49.—THE STOMACH OF A SHEEP
Showing the four compartments. (Huxley)

Next comes the stomach lining proper. If this is seen when the stomach is empty, there appears to be a series of wrinkles or folds, going lengthwise of the organ, from the pyloric to the cardiac regions; these folds are spoken of as **rugæ**; Fig. 48. Furthermore, if any part of the inner wall, on or between the folds, were to be examined with a lens, the appearance would be that of innumerable tiny pits, of polygonal shape, giving to the whole the semblance of an extremely fine celled honey-comb. These pits are scarcely over one one-hundredth of an inch in diameter, and in the bottom of each is a minute opening through which **gastric glands** pour a secretion. The glands are short and cylindrical, thousands in number, and can be compared to tiny tubes lying side by side, with their mouths opening into the stomach cavity; Fig. 50. Each of these glands is lined with large cells which make **gastric juice** from the

FIG. 50.—A SINGLE GASTRIC GLAND
Very highly magnified.

blood that flows around them, and pour it into the cavity of the gland, whence it flows into the stomach.

### COMPOSITION AND ACTION OF THE GASTRIC JUICE

Water makes up over 99% of the gastric secretion. Of the remainder 0.3% is **pepsin,** 0.2% **hydrochloric acid** and 0.1% **sodium chloride** (common salt). Less in quantity, but important, are the two ferments **rennin** and **gastro-lipase**. The work of the gastric juice is two-fold. 1. *It softens the solid foods,* which are consequently easily broken up into shreds by the active churning motion of the stomach. Meat, for example, is made up of great numbers of little fibres bound together into a solid mass by connective tissue. This tissue is dissolved away by the gastric juice, thus setting free the fibres and allowing the liquids to act further on each separate fibre. The fat of the meat is also set free from the masses in which it is swallowed, and is melted by the heat of the body into oil. This softening action is performed chiefly by the acid and water of the gastric secretion, not by the pepsin.

We shall presently see that all foods are digested in the intestine even more vigorously than in the stomach. But stomach digestion is a very important factor, for while the proteids themselves can be acted on in the intestine, the connective tissue that holds the muscle fibres together, will be less quickly dissolved there because of the absence of acid in the intestinal secretions. Without the influence of the gastric juice the muscle fibres will not be readily set loose so that the juices may act upon them. "Stomach digestion" is thus an important preliminary to "intestinal digestion."

2. Gastric juice *produces a great chemical change in the proteids.* Strange as it may seem at first sight, these very important foods, of which meats, milk and eggs are typical examples, cannot be taken through the wall of the intestine, into the blood or be of any use to us unless they first cease

to be proteids. They *cannot be absorbed as proteid* even though our own muscles and blood are largely of proteid material. The change which proteids must go through is a chemical one, and the first step toward it is brought about by the hydrochloric acid and the pepsin in the gastric juice. This pepsin is one of the ferments, or enzymes, to which attention was directed in an earlier chapter, and under its influence the proteids, which are very complex bodies, are broken into simpler ones. These new bodies, peptones, proteoses, and allied substances, are no longer real proteids but are far simpler chemically, and may readily pass through the wall of the stomach. It is probable, however, that a large part of the proteid eaten is carried on into the intestine and still further modified before absorption.

Milk contains much proteid in the form of casein. This casein, however, is not readily acted on by pepsin until the milk is curdled. **Rennin,** the second enzyme in gastric juice, produces the curdling action on milk. It is from a similar curd that cheese is made, cheese-makers adding to their milk rennet which is usually obtained by a process of extraction and refinement from the stomachs of calves. Calves' diet consists mainly of milk and their gastric glands contain great quantities of rennin.

From these facts it is evident that milk taken into the stomach is speedily soured by the acid in the gastric juice and curdled by the rennin. If a baby vomits, and its milk is found to be curdled and sour it may indicate that the child has eaten more than it can comfortably hold in its stomach, but the changes in its food only show that digestion is going on properly.

On sugars and starches gastric enzymes have practically no effect. Indeed, the digestion of starches which was begun by the saliva in the mouth stops after the food has become mixed with the gastric juice, because the salivary enzymes will not act in an acid solution, and there is considerable acid in

the gastric juice. It takes some time, however, for the swallowed food to become thoroughly mixed with the gastric juice and therefore, for perhaps an hour after reaching the stomach, the conversion of starch into sugar continues.

For a long time it was held that fat undergoes only melting and emulsification in the stomach; but more recent studies show the presence, in a limited way, of a third ferment, **gastro-lipase,** which changes fats into glycerin and fatty acids. Absorption of fats is now possible, but probably this does not occur till they have gone on into the intestinal division of the alimentary canal.

**The Flow of the Gastric Juice.** — Between meals, when the stomach is practically empty, its walls are of a pale pink color, and the lining is merely moist; very little secreting work is done by the glands. But, on the entrance of food, the blood vessels in the stomach walls expand, and more blood flows around the glands, the cells of which begin a copious secretion. Like the case of the salivary secretions, this response of the blood vessels and glands is a reflex action, controlled by the central nervous system. The actual contact of the mouth or stomach

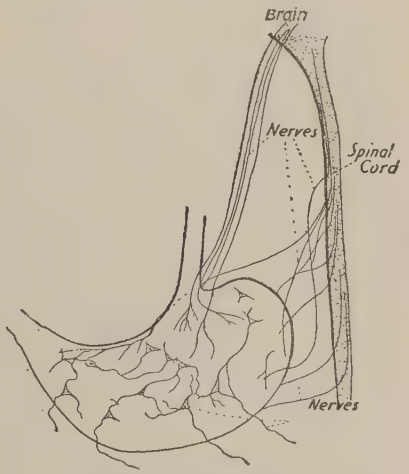



FIG. 51.—DIAGRAM

Showing the method by which the stomach receives its nerves from the brain and cord. The nerves from the cord actually come through the sympathetic system, not shown in the figure. (Modified from Openchowski)

with food is not necessary since the mere sight or smell of food is all that is required to produce the result. The stomach does not regulate itself; it acts only at the command of the brain; Fig. 51.

It is necessary, however, that the person be conscious, or secretion will not occur. If food is put into the stomach of a sleeping dog, no gastric secretion, and, therefore, no digestion occurs. Again, more is secreted when one is hungry than when one swallows food though not hungry. Pleasant tasting foods stimulate more active secretion than unpleasant, and thus we can conclude that pleasing flavors, although they may have no food value, may have a decided use as aids in digestion.

Sometimes when a person's digestion is poor, so-called **predigested foods** are taken. These are generally proteid substances which have been treated artificially with pepsin obtained from the stomachs of pigs. This predigested food can be handled by the stomach more easily than ordinary food; but its use should not become a habit, for constantly aided in this way the stomach and other organs become dependent on this assistance and lose their natural powers.

Cold, as a rule, retards the action of any gland, muscle or other tissue in the body, while heat, within limits, is favorable to their action. In the stomach the glands, together with the nerves which control them, are so near the surface that large quantities of cold food, like ice cream or ice water, produce a shock which always delays their normal action. The distinct pain caused by too warm food or drink prevents us from harming ourselves in this way. It is interesting to note in this connection that heat as such, is not felt when food is swallowed; the sensation is one of pain only.

**The Passage of Food into the Intestine.**—The length of time that food remains in the stomach varies with the kind of food, but in the course of two to four hours after the average meal, all foods have become a finely divided, slimy mass called

**chyme.** In this mass after an ordinary meal, there should be *water, saliva, mucus, gastric juice, peptones, unchanged proteid, dissolved sugars, unmodified starches, curdled milk, fat droplets, shreds of connective tissue and vegetable cellulose,* the woody substance in plant structures. Responding to the presence of this chyme, the muscles in the pyloric valve relax and allow the food to pass on into the small intestine.

The mere presence of chyme in the stomach does not provoke the pyloric valve to open and let it pass through. This would obviously be poor management should it happen that the duodenum were already full, and completely busy with its work on chyme previously received. It will be remembered that chyme is acid, as a result of hydrochloric acid in the gastric juice. In contrast, the juices of the intestine are alkaline; but it takes some time for the intestinal secretions to overcome the acidity of material received from the stomach. When this acidity is finally neutralized, however, a message is sent from the intestine to the pylorus that all is in readiness for a further installment of chyme from the stomach, and the valve opens. Very unexpectedly this message is sent, not through nerve fibres as most stimuli are, but through the blood stream; this is a round-about method, but it is the one used in this instance.

## CHAPTER VII

## DIGESTION OF FOOD: THE INTESTINE

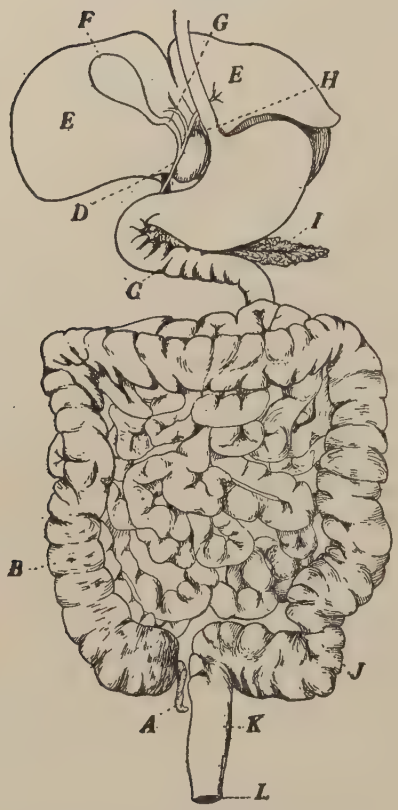



FIG. 52.—THE DIGESTIVE ORGANS IN THE ABDOMEN

The stomach and liver are separated for clearness' sake. They are really in close contact.

*A*, appendix; *B*, large intestine; *C*, duodenum; *D*, bile duct; *E*, liver; *F*, gall bladder; *G*, cystic duct; *H*, hepatic duct; *I*, pancreas; *J*, sigmoid flexure; *K*, rectum; *L*, anal aperture.

MANY people have a mistaken idea that the stomach is the all-important section of the food canal, the chief organ of digestion, and that almost as soon as food is swallowed it becomes transformed by some marvellous influence into energy, heat, muscle or brain. We frequently hear a man say that he needs a hearty dinner because he is to work hard in the afternoon, thus wrongly assuming that the dinner of the day furnishes him with immediate muscular power. But little if any food is absorbed from the mouth or gullet, and little from the stomach. Food is of no value until it has left the stomach and, not for many hours after eating does any portion of it become a part of the body itself. The power to do each day's work comes from the food eaten the day before or, perhaps,

several days before. Food, after leaving the stomach, must still pass through a long series of changes before it is of any practical value.

The intestine may be considered in two sections: the small intestine and the large. The former is about twenty feet in length, and the latter about five; the total length below the stomach affords, therefore, a large amount of surface for absorption; Fig. 52.

### THE SMALL INTESTINE AND ORGANS CONNECTED WITH IT

The **small intestine** commences at the pyloric valve of the stomach and extends, coiling much on the way, to a point in the right, lower part of the abdominal cavity, where it enters the large intestine. Its average diameter is about one inch. It occupies practically all the space in the lower half of the abdominal cavity, save that taken by the large intestine, the kidneys, bladder and spleen. Throughout its length it is loosely attached to the dorsal wall of the cavity by a thin sheet of tissue, the mesentery. This mesentery is traversed by a multitude of arteries and veins on their way to and from the digestive tract; for it is solely through these vessels that food is taken up from the food canal and carried over the body; Fig. 53.

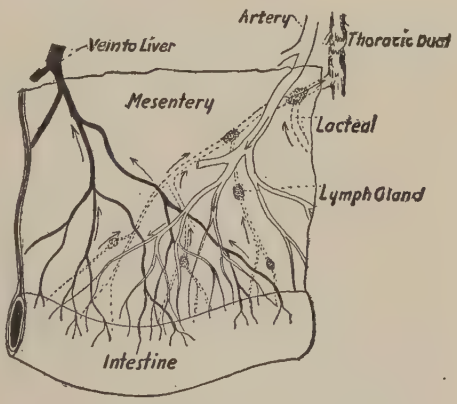



FIG. 53.—DIAGRAM

Showing a piece of the intestine held in the mesentery and the blood and lymph vessels in it.
The mesentery is represented as narrower than it actually is and hence the lymph glands as closer to the intestine.

After the food has been in the stomach for an hour and a half or two hours, the valve which has kept it from going into the intestine opens and allows a little of it to pass out, closing again quickly. Soon it opens again and more of the digested food passes out, for this valve operates like a very sensitive mechanism which allows softened, partly dissolved food to pass it, but closes at once if any solid, undigested food touches it. The food thus passes out of the stomach, a little at a time into this long tunnel, where it is to be still further dissolved and changed for absorption. Through this tube the food is slowly pushed along by peristaltic action of muscles in its walls, similar to those in the œsophagus. Almost at once after leaving the stomach the intestine makes a bend downward and to the left, thus crossing the abdomen below the stomach as the **duodenum**; Fig. 52. As the food mass is carried around this bend it is mixed with a secretion which enters the intestine by a duct shown in Figure 48, and which comes from two large and very important organs, the **liver** and the **pancreas.**

In many backboned animals these two organs connect with the intestine through separate ducts, while in others their ducts join as in man. The spleen, which is near by, has no connection with the intestine physiologically.

**The Liver and its Functions.**—The liver is a large gland, weighing in a person of average size about three pounds, and located just below the diaphragm.

It is partially divided into a number of lobes. There is a large right, a smaller left lobe, and other smaller divisions, which easily adjust themselves to the neighboring organs. The stomach over which its lobes hang is very active; the body walls are constantly moving, and the diaphragm pulls the organs up and down as one breathes. To all this environment, the liver adjusts itself, its lobes gliding easily over one another, as well as over the organs with which they come in contact.

Everyone is familiar with the dark red appearance of the

beef's liver as it hangs in the markets. This red color is partly due to the fact that the organ is very full of blood; it has been estimated that one-quarter of all the blood of the body may be in the liver. Its surface shows a mottled appearance, due to the arrangement of tissues in the organ, for it is really a large compound gland; Fig. 54.

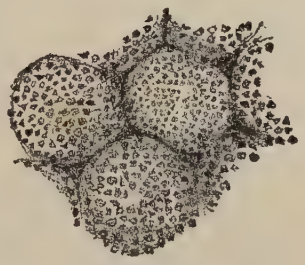


FIG. 54.—THE SURFACE OF THE LIVER
Slightly magnified

Beneath the right lobe is the **gall bladder,** a pear-shaped sac, about four inches in length, and at its widest place an inch in diameter. Its function is that of a storage reservoir for holding the **bile** secreted by the liver when it is not needed in the intestine. From an examination of Figure 52, it will be seen that the bile does not run directly from the liver into this sac, but that the only duct leading away from the organ, the **hepatic,** goes in a fairly direct line to the first loop of the intestine. A side branch from this, the **cystic duct,** leads to the gall bladder; from their junction to the intestine, is a tube called the **common bile duct.**

The liver keeps steadily secreting but the demand for bile is not constant, as food conditions in the intestine are not always the same. When bile is not needed in the intestine the common bile duct closes, and the bile, then coming from the liver, goes back and is stored in the gall bladder (Fig. 48); there it accumulates until the opening into the intestine again allows a free flow. The presence of chyme coming from the stomach causes such an opening.

The large size of the liver and its abundant blood supply suggest that the organ must have very important uses. The amount of fluid which it secretes daily varies in different persons from a pint to a pint and a half; it is a little thicker than water, and of a golden brown color. Notwithstanding this

abundant secretion, which amounts to about one and one-half pints per day in an adult, it is surprising to learn that until recently little was known as to the value of bile as it mixes with food materials in the intestine.

At least three uses for it are now recognized; of these the most important is that it intensifies the action of pancreatic juices about three-fold. Another function is the dissolving of fatty acids and making them more absorbable; when its flow is prevented, not only is fat only partially digested and unabsorbed, but a fatty coating adheres to other kinds of food and prevents digestive jui es having access to them, thus letting them pass from the body unused. Bile also prevents rapid growth of bacteria in the intestine with consequent putrefaction and gas formation, though by itself it deteriorates easily.

Other important functions of the liver will be pointed out in their proper connections later.

FIG. 55.—A HIGHLY MAGNIFIED VIEW OF A BIT OF THE PANCREAS SHOWING ALVEOLI (Maziarski)

**The Pancreas and its Functions.**—Unlike bile, the fluid secreted by the pancreas plays a necessary part in the digestive process. As can be seen from Figure 48, a duct from the pancreas joins the common bile duct just before the latter enters the intestine.

The **pancreas** is what the butcher calls the "sweetbread." In the human being it is about seven inches long by one and a half broad, and one-half inch thick; not a very large organ but of great importance. It is spongy in texture, and lies, attached loosely, along the lower curved border of the stomach. Its structure, as shown in Figure 55, is very like that of the salivary glands. The liquid output of its cells amounts to about one and one-half pints a day, and is clear and watery in appearance.

contrast to the acid secretions of the gastric glands, the pancreatic secretion is *strongly alkaline.*

Food as it leaves the stomach is by no means completely digested. The starch is only partially changed to sugar; much of the proteid passes through the stomach without change, and the fats, though melted and emulsified in part, have been only partially digested, if at all.

The fluid derived from the pancreas has the power to dissolve and change any kind of food, this being accomplished for the most part by three different ferments (enzymes), as follows:

1. **Trypsin,** which starts the digestion of proteids by changing many of them to peptones, thus supplementing the work of the gastric juice.

2. **Amyolopsin,** which converts starches into sugars, thus completing the action of the saliva.

3. **Lipase** (**steapsin**), under the action of which fats are split up and made absorbable, i. e. digested.

The influence of trypsin is similar to that of pepsin although more complete; it also acts upon the proteids which have been partly changed into peptones, and breaks them up still further chemically; this action continues till all proteid material has been reduced to very simple substances called amino-acids. These differ from proteids in that they are composed of much smaller molecules, are soluble in water, do not coagulate with heat, and easily pass through membranes. Probably most, if not all, the peptones are changed into amino-acids before absorption, this final step being brought about by a ferment, erepsin, secreted by the intestinal wall glands.

About eighteen different amino-acids are now recognized as resulting from the complete digestion of different sorts of proteid foods. Some of these, e. g. arginine and glutaminic acid, are abundant, i. e. derived from many proteid sources; others, e.g. cystine, are seldom formed; tryotophane (derived from milk and wheat) and lysine (from milk and eggs) are very essential to growth, while glutaminic acid (from milk, eggs, wheat, peas,

etc.) is a proteid product with very limited food value.

We thus see that there is a genuine basis for the arguments which insist on a varied diet; for not all the substances in even the so-called "best foods" have real nutritional value.

**The amylopsin** acts upon starches much as does **the ptyalin of saliva** and completes their change into sugar.

The steapsin acts upon the fats causing their digestion. Two very different changes take place in them. First, much of the fat is broken up into extremely minute droplets, which float in the liquid of the food. In this condition it resembles the fat of milk and, indeed, the entire contents of the intestine, because of this condition of the fat, become more or less white like milk. Such a condition of finely divided fat droplets is called an emulsion; Fig. 56. It was formerly thought that these fat droplets were absorbed directly through the walls of the intestine into the blood; but it is now known that a second change takes place in part of the fat, if not in all, before it is really absorbed.

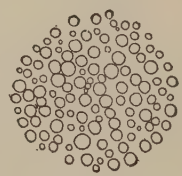


FIG. 56.—EMULSIFIED FAT
Showing fat droplets; highly magnified.

This is a chemical change which results in splitting up the fat molecules into two different substances called **fatty acids** and **glycerine** — both of which are easily absorbed. Their reformation into fat occurs very promptly, however, for true fat droplets are found abundantly in the lining cells of the intestine, immediately after fat digestion. See Fig. 64.

No digestive gland has such varied and efficient powers as the pancreas. The pancreatic fluid digests any food that has not been acted on by the other digestive juices. Some foods, especially complex sugars, may be simplified by enzymes, e. g. maltose (which acts on starch-sugars) and **lactose** (which modifies milk-sugar) occurring in juices which are added to the food mass by cells in the intestinal lining.

After the food is completely digested, it is wholly changed in nature and appearance. It was swallowed as meat, potatoes, bread and butter or milk; it has become dissolved into a

whitish, syrupy liquid, called **chyle,** in which there are but few remnants of solid material. Its proteids have become peptones or even simpler bodies; its starches are all sugars; and its fats are either emulsified or are changed into fatty acids and glycerine. It is not until the food has flowed through a considerable section of the intestine that digestion is complete.

The walls of the small intestine, shown in Figure 57, are composed of muscles that force the food along, of glands, the secretion of which resembles that of the pancreas, and of villi (described in the next chapter).

FIG. 57.—A CROSS SECTION THROUGH THE WALL OF THE SMALL INTESTINE (Modified from Oppel).

### THE LARGE INTESTINE

The small intestine empties into the **large intestine** in the lower right side of the abdominal cavity. The opening from one to the other is little more than a slit, the sides of which open easily in one direction but not in the other; Fig. 58. Hence food passes readily onward, but not backward. The part of the large intestine thus entered is the **colon,** and the general shape of the course which it takes is that of an inverted letter U; i. e. beginning on the lower right side of the body cavity it passes up that side as far as the liver (**ascending colon**); then it crosses to the left side of the body (**transverse colon**), and there passes downward (**descending colon**); Fig. 52.

The small intestine *opens into the side* of the large intestine (see Figs. 52 and 58); about two and a half inches of the latter are thus left below the opening as a short section ending blindly and called the **cœcum,** a word meaning "blind."

From the lower end of the cœcum protrudes a short hollow tube called the **vermiform appendix**; this varies in size in different people but it is usually from three to six inches long, and a quarter of an inch or more in diameter. The cavity opens into the cœcum.

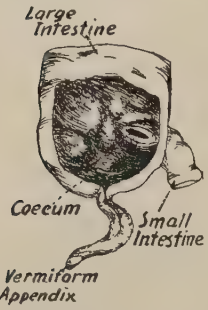



FIG. 58.—THE BEGINNING OF THE LARGE INTESTINE
Showing the opening from the small intestine at some distance from its end.

Beyond the lower end of the descending colon the intestine passes into an S-shaped portion called the **sigmoid flexure**; from this all intestinal contents enter the final section of the digestive tract, the **rectum.** This opens to the exterior by the anal aperture; Fig. 52.

The walls of the large intestine are constructed practically like those of the small; but there seem to be no glands opening into it which are concerned with the digestion of food, though mucous glands are numerous. The food may not be wholly digested in the small intestine and so digestive processes, to a small extent, go on here although not by virtue of the glands of the large intestine itself. There is also very rapid absorption from this region, particularly of water, and this causes the intestinal contents to become more and more hard. Much of this " undissolved food " performs a valuable service, however, by mechanically stimulating the walls of the intestine and thus causing more rapid peristaltic action. A more certain passing along of food materials is thus ensured and so the trouble called **constipation** is, in a measure, prevented. If only very fine foods, e. g. those made from finely powdered flours, are eaten, the water in them may be absorbed quickly and then the mass becomes so dry and unyielding that it is forced along the canal with great difficulty. Coarse foods, which are sometimes refused by persons who proudly consider them too crude and cheap for their

refined taste, are often not only very nutritious, but as a rule necessary for uniformly good digestion and therefore good health. Those materials which are not changed into a liquid condition are never absorbed and never become parts of the body.

After the nutritive part of the intestinal contents has been absorbed there remains a considerable portion of undigested matter which is now useless and is passed to the exterior as **fæces.** The elimination of these wastes once a day is of almost as much importance to health as the regular taking of food. The intestinal contents after food absorption readily undergo putrefaction from the growth of bacteria and soon become filled with poisonous substances which injure the body materially if the wastes are not regularly removed. Their retention is apt to result in headaches or other bodily derangements. Disturbances by which the wastes are retained too long (constipation) or by which they are discharged too frequently and in too liquid condition (diarrhea) are both to be avoided. Such conditions are due as a rule to an error in methods of living. One may be eating improper food; he may be eating too much food or too often; he may be eating too much fine food like wheat flour and not enough coarse food or he may not be drinking enough water. He may be living a too sedentary life; constipation especially is frequently due to insufficient exercise and may be remedied by various forms of bodily activity. The improper method of fighting these troubles is to use medicine; for drugs only palliate and do not cure them. Regularity in expelling the waste largely depends upon *habit.* A little care and attention will enable almost any one to acquire regular habits that will be of lasting value to his general health. No one whose intestine is crowded with poisoning wastes can continue in good health.

### DIGESTION OF DIFFERENT FOODS

Since no food can be absorbed into the body until it is digested, the readiness with which a food can be digested is a

factor in determining its value. Cheese is the most nutritious of our foods, but it is such a condensed food that only a little of it should be eaten at one time. Peas and beans are also very nutritious foods, containing a large amount of proteid; but these again are too difficult of digestion to be used like bread, as a constant article of diet. The digestive tract, however, can perfectly well handle a considerable amount of foods that are difficult to digest and it is better to use some of them rather than to give the digestive organs too easy a task. But in choosing one's diet, it is well to bear in mind that foods like milk, bread, rice, soft boiled beef, mutton and broiled meats are more easily utilized than are beans, peas, nuts, hard boiled eggs, pork, veal, fried foods and cheese.

### ALCOHOL AND INDIGESTION

Various opinions have been held as to the effect of alcohol on digestion. That it produces serious troubles when used in large amounts is questioned by no one, but it has been a popular belief that when used in small quantities it aids digestion. The most careful testing of this theory has shown that it is a mistake. Alcohol has two opposite effects upon digestion. It causes increased secretion of some of the digestive juices, chiefly the saliva and gastric juice. To this extent it might be supposed to promote digestion. But, on the other hand, its presence in the stomach tends to weaken the action of the digestive ferments and this serves to counteract the apparent advantage of the increased secretion. As a result, when used in small quantities alcohol neither hastens nor retards digestion; when used in larger amounts, its retarding action is always certain.

With certain alcoholic drinks, the retarding action is especially evident and, oddly enough, this is true of many wines that are not infrequently taken as " appetizers " with meals, under the false impression that they facilitate digestion. Experiments with these wines show that they have a very

considerable checking action upon digestion, greater than that of pure alcohol. The effect is due in these cases to other substances in the wines as well as to the alcohol.

In short, it is an established fact that alcoholic drinks are, at least to healthy persons, of no use in digestion and rarely if ever of value in illness. On the contrary they are usually, and perhaps always, a direct detriment. It is not strange, however, that persons who have used wine for a long time think that it aids digestion since they have by its use brought their bodies into a condition in which the digestive glands will not act normally without it.

### DISEASES OF THE INTESTINAL TRACT

**Summer Complaint.**—Very often something one has eaten produces a quick and rather violent disturbance of the digestive organs; a feeling of nausea, followed by vomiting, frequently by pain in the stomach and bowels, occurs, and perhaps also diarrhea. The cause is often hard to determine exactly, but the trouble is practically always due to improper food or drink. It is common in hot weather and therefore has been called *summer complaint.* While sometimes violent, it is usually not serious, and under ordinary conditions will pass away in a day or two if the person remains comparatively quiet and is careful as to what he eats.

**Peritonitis.**—We have noted that the abdominal cavity is lined with a very delicate membrane in a fold of which the intestine is held. These tissues sometimes become inflamed, the many blood vessels in them becoming distended. At the same time the sensitiveness of the parts becomes very great, and much pain is felt in the abdomen. The condition is known as **peritonitis,** a word derived from peritoneum, the name of the abdominal lining. Peritonitis may be very serious and even fatal; for in its severe form the blood vessels may burst, causing exudation into the abdomen and other serious complications. It is characterized by continued pain in the ab-

domen which must not be confused with an ordinary stomach ache due to improper eating.

**Appendicitis.**—We have already noticed the vermiform appendix (Fig. 52) which opens into the large intestine by a small aperture. It occasionally happens that an inflammation starts in the appendix; it becomes swollen, and its blood vessels expand, causing pain and soreness on the right side of the abdomen, which shows the presence of **appendicitis.** This disease is a very serious one; for if pus accumulates in the appendix and it is not drained off through the lumen into the intestine, the appendix is likely to burst, the pus escaping freely into the abdominal cavity. When this occurs it is commonly followed by general peritonitis, with fatal results. The serious nature of the trouble makes it advisable to consult a physician when symptoms such as above described are felt. The majority of cases may be cured by the removal of the appendix, a surgical operation which, if performed in time, involves little danger.

The real inciting causes of peritonitis and appendicitis are not yet thoroughly understood and at present we know of no rules for avoiding them.

FIG. 59.—TYPHOID BACILLI
The cause of typhoid fever.

**Typhoid Fever.**— Typhoid fever is caused by the entrance into the intestine of a well known bacterium (Fig. 59) which grows abundantly there and excretes poisons which affect the body tissues. There are certain definite symptoms of the disease, one of which is a fever that may last several weeks. Doctors can do little to cure it beyond maintaining the strength of the body so that the person may have the power to drive off the trouble himself. It is one of the most serious illnesses, and it causes many deaths each year. About 10% of those taking the disease die, and many others are incapacitated for work by it for weeks or months, and sometimes permanently. It is more common in the fall than at any other season.

The sources from which one is liable to obtain typhoid

bacteria are well known. *Drinking water,* if in any way polluted with sewage, is almost certain to contain typhoid germs. Hence, water from brooks, reservoirs, rivers, lakes or wells that receive any sewage is unsafe to drink.

Milk is also a source of typhoid infection. If there is a case of typhoid fever at a farm where milk is produced, the germs are pretty sure to get into the milk. Oysters which have been placed near the mouth of a river for the sake of "floating" them are also occasionally infected with the bacteria, and if eaten uncooked, cause the disease. Flies are apt to carry the germs on their feet and deposit them on the food upon which they feed.

To avoid the dangers of typhoid fever one should drink none except the purest water, be especially careful of the milk supply, and not allow flies to alight on food or dining tables. Both water and milk can be made perfectly safe by boiling.

A very successful method of avoiding typhoid fever is by an inoculation with anti-typhoid vaccine. This is injected under a person's skin and thus renders him immune against typhoid fever for two or three years. It is very widely used with soldiers, and it is wise for persons who are to travel, where they cannot properly control their food and water, to thus protect themselves.

**Hookworm.**— This disease is caused by a small parasitic worm. A person becomes infected sometimes by taking these worms into the mouth with food or drink, but more commonly by getting dirt containing them onto the hands or feet. They usually find their way to the intestine where they may live for a long time. The symptoms of the disease are a dry or yellow skin, anæmia (paleness), stupid facial expression, emaciation, irregularities in appetite and breathing, weakness in the muscles, headache, defective mentality, and some others. The disease is quite easily cured by treatment with thymol. This disease is very common in the South, especially among those who go barefoot, since they are very easily infected through their feet.

## CHAPTER VIII

## THE ABSORPTION OF FOODS

It is very natural to compare the body to a factory and the alimentary tract to the furnace room where fuel is being burned. In both factory and furnace there is motion, work is being done and heat is being produced.

This comparison is not, however, entirely applicable. In a factory the fuel is burned in the furnace, only the heat from the flames passing through the furnace walls. In our bodies, on the contrary, the materials themselves in the digestive tract pass through the intestinal walls and are transported around the body. No heat at all comes from the digestive tract, for the food gives up none of its stored-up properties until it has passed out of this tract and been carried to its final destination in the hands, in the brain, in the liver or elsewhere. The intestine is therefore not properly comparable to a furnace

A better analogy would be to compare the human body to a city, from the gas plant of which gas is sent to different parts of the city; some of it is to be used for cooking, some for lighting, some for heating. Some of the heat is, perhaps, employed for producing steam pressure in an engine, which in turn runs a sewing machine, a lathe or a water pump. The material used in producing the heat is prepared in one part of the city, but it gives off neither heat nor power nor light there, nor while going through the pipes. It is really used only after it has reached some little nook or corner, in attic or basement, sleeping room, kitchen or shop; there it gives out its light, heat or power.

### STRUCTURES CONCERNED IN ABSORPTION

We have traced the food to the intestine and noted it there in the form of chyle, ready to be absorbed. The small in-

testine is practically a tube within a tube, the outer of which is for the most part muscular. If we imagine the inner tube to be longer than the outer, the inner tube will consequently be thrown into ridges which go transversely around it, intruding on the cavity more or less. Some but not all of the ridges will pass entirely around the tube; Fig 60. Furthermore the whole lining, ridges and all, is covered with minute, flexible projections, almost as if there were tiny fingers protruding into the food mass of the intestine. These fingers are called **villi**, and they take the food from the intestine by a method of their own. They are just long enough to be seen with the naked eye; Fig. 61.

FIG. 60.—APPEARANCE OF THE INTERIOR OF THE INTESTINE
Showing the folding of its lining.

Into each villus extends a nerve and also a tiny branch of one of the **arteries** in the intestinal walls. This arteriole extends nearly to the end of the villus and there breaks up into much smaller blood vessels, which thus form a sort of network; Fig. 62. After passing through this network and picking up food in a manner to be described presently, the blood returns again through veins to the intestinal wall and is then carried off once more into the body. Each villus contains another tube also (Fig. 61), called a **lacteal,** which receives the fats of the food. A single layer of cells, the **epithelium,** covers each villus and separates the blood vessels and lacteals from the liquid contents of the intestine.

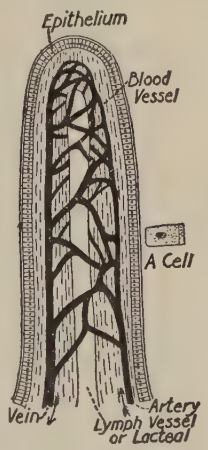



FIG. 61.—A SINGLE VILLUS
Highly magnified.

## OSMOSIS

How is food actually absorbed through the intestinal walls? Two liquids, the blood and the dissolved food, are separated by a thin moistened membrane. How is it possible for the liquid to flow in one direction and not in the other? In other words, why does the liquid food go through into the blood vessels, and the blood at the same time not pass out into the intestine? Physiologists are as yet able to give only a partial answer to this rather puzzling question.

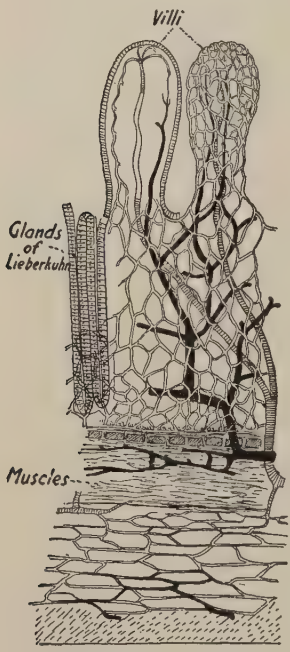



FIG. 62.—SHOWING THE MINUTE BLOOD VESSELS OF THE VILLI AND INTESTINAL WALLS

The arteries are striped, the veins black and the capillaries open. (Oppel)

Food absorption depends partly upon a process called **osmosis.** In the first place it is not quite true that food passes from the intestine, and that nothing passes in the other direction; for a certain amount of liquid does pass into the intestinal canal from the blood. But the latter is small in amount, perhaps chiefly water, and more material passes in the reverse direction. To show how such a transfer could take place, an illustration will be useful. Procure a piece of membranous tube, like that used for the covering of sausages. Fill this with a solution of pure grape sugar and suspend it in a jar full of water, as shown in Figure 63. The tube may thus represent the intestine full of digested food, and the

water around it may represent the blood. Under these conditions there would seem to be no special reason why there should be a flow of liquid in either direction; but nevertheless, as a matter of fact, the contents of the tube soon begin to flow out through the wall of the tube into the jar and at the same time water flows into the tube. They flow at different rates of speed, however, in the two directions, the water, in this particular case, flowing into the tube much more rapidly than the sugar solution flows out. This process is called osmosis.

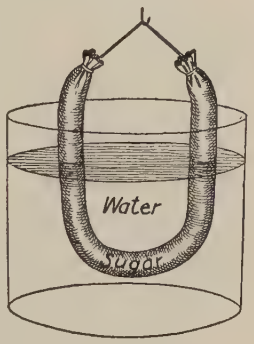



FIG. 63.—DIAGRAM ILLUSTRATING OSMOSIS

Since the membrane contains no holes large enough to be seen with a microscope, the condition in which water or any other liquid could pass through it must necessarily be that of a very fine state of division, doubtless in what chemists call molecules. Molecules are the smallest forms which any substance can take and yet maintain its own characteristics and are, of course, invisible. It is known, however, that molecules are of different sizes, a sugar molecule containing practically eight times as many parts (atoms) as a water molecule. If, then, sugar molecules and water molecules are mingled inside the tube, and only water molecules are on the outside, many more water molecules are in contact with the membrane on the pure water side than on the other; for each sugar molecule takes up much of the space on the inside of the tube.

Physicists tell us that all molecules are in very rapid motion, though each, in a general way, remains in its own "playground." These molecules of water and sugar then are constantly hitting against the walls of the membranous tube, and some will pass through the infinitesimally small pores in it.

## OSMOSIS

How is food actually absorbed through the intestinal walls? Two liquids, the blood and the dissolved food, are separated by a thin moistened membrane. How is it possible for the liquid to flow in one direction and not in the other? In other words, why does the liquid food go through into the blood vessels, and the blood at the same time not pass out into the intestine? Physiologists are as yet able to give only a partial answer to this rather puzzling question.

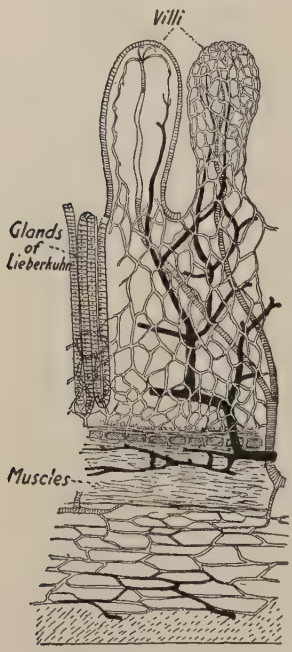



FIG. 62.—SHOWING THE MINUTE BLOOD VESSELS OF THE VILLI AND INTESTINAL WALLS

The arteries are striped, the veins black and the capillaries open. (Oppel)

Food absorption depends partly upon a process called **osmosis.** In the first place it is not quite true that food passes from the intestine, and that nothing passes in the other direction; for a certain amount of liquid does pass into the intestinal canal from the blood. But the latter is small in amount, perhaps chiefly water, and more material passes in the reverse direction. To show how such a transfer could take place, an illustration will be useful. Procure a piece of membranous tube, like that used for the covering of sausages. Fill this with a solution of pure grape sugar and suspend it in a jar full of water, as shown in Figure 63. The tube may thus represent the intestine full of digested food, and the

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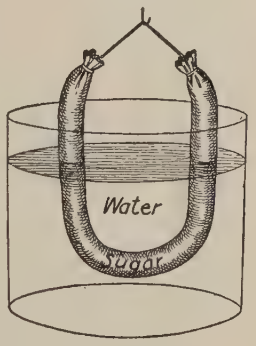


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Physicists tell us that all molecules are in very rapid motion, though each, in a general way, remains in its own "playground." These molecules of water and sugar then are constantly hitting against the walls of the membranous tube, and some will pass through the infinitesimally small pores in it.

Both sugar and water molecules will pass through, but the sugar molecules, since they are larger, will not penetrate as fast as water. Hence, there will be much more water going into the tube than sugar going out. Nevertheless, if we leave the tube in the jar long enough the sugar will continue to pass out till the solution in the jar becomes as sweet as that in the tube. After this, no noticeable exchange occurs. But if we should then remove the water, which by this time would contain some of the sugar, and replace it with fresh water, once more putting the tube in it, the sugar would then continue passing out. If we continued to renew the water in the jar as fast as it became charged with the sugar we could keep the sugar flowing out of the tube into the water of the jar until all of the sugar was gone from the tube, and only pure water was left in it.

**Food Absorption.**—Now, this process of osmosis does not fully explain the manner of food absorption, but it does explain certain phases of it. Physicists find that some substances will thus pass through membranes while others will not. The former they call **crystalloids,** the latter **colloids.** Most of our foods, when eaten, are of such a character that they will not pass through membranes, and could not be taken through the intestinal walls; but digestion changes them, until finally they are in a form that will readily diffuse. Starches and proteids, for example, will not diffuse, while sugars and peptones will. Thus, digestion brings the food into a condition in which it can be absorbed.

In the intestine digested food is on one side of the membrane formed by the epithelium of the villi, while on the other side is blood; the membrane thus has different liquids moistening its two sides. Under these conditions the dissolved food begins to flow through into the blood vessels, and as fast as the blood present becomes filled with the absorbed food, it is carried off and fresh blood takes its place. This continues

until nearly all the digested portion of the food has passed out of the intestine into the blood.

But meantime, according to our illustration, water has been passing from the blood into the intestine. Here, however, the illustration partly fails; for while doubtless some of the water of the blood does enter the intestine, it does not do so as fast as it would in the illustration. Exactly why this is so, physiologists do not fully know. So it must be conceded that the real secret of food absorption is not entirely understood, and we have merely to say that it occurs because of the nature of the *living cells* in the intestinal walls. The membrane of the villi is made of living cells and these cells, when alive, act differently from those of non-living tubes.

### CHANGES IN FOOD AFTER ABSORPTION

We can now understand that the first purpose of digestion is to bring the foods into such a condition that they can pass through the intestinal walls. Further changes occur in them, however, after their absorption. The proteids, for example, are by digestion broken into very simple compounds, but after these are taken into the blood they are built up into proteids again. Just where and how this occurs is not yet known; but it is known that proteids are abundant in the blood although only the simple products of proteid digestion are absorbed. Somewhere, therefore, they are reconverted. A further change also takes place

FIG. 64.—A HIGHLY MAGNIFIED VIEW OF THE TIP OF A VILLUS

Showing the absorption of fat. The black dots are fat.

These substances are also taken into the villi (Fig. 64), but not into the blood vessels; they enter the single tube, the lacteal, in the center of each villus, and during their absorption appear to be again united into true fat. Although physiologists do not know just where or how this occurs, the fact that true fat rapidly collects in the lacteals during absorption would seem to indicate that the fat is broken up simply to enable it to be absorbed through the intestinal walls.

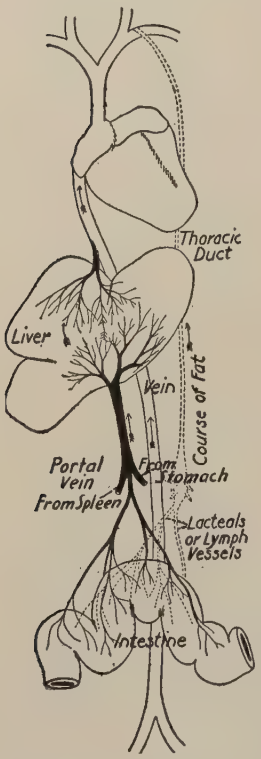



FIG. 65.—DIAGRAM OF THE VENOUS CIRCULATION OF THE INTESTINE AND LIVER

### THE PATH TAKEN BY THE ABSORBED CARBOHYDRATES AND PROTEIDS

Proteid foods and carbohydrates both pass directly into the blood vessels. The veins carrying this blood away from the viscera unite and form one large vessel, called the **portal vein**; this goes to the liver, where it divides into very minute branches; Fig. 65. After passing through the liver, the blood collects once more and flows to the heart. This portal vein, which with these same relations occurs in all backboned animals, is the only vein in the body which breaks up into branches in the liver on its way to the heart. All the others run directly to the heart.

Why should the blood from the intestine be thus distributed through the liver? It is evident that soon after each meal the largest amount of food stuff is present in the portal vein. If this should pass immedi-

ately around the body, the various tissues would have an over-supply of foods for a few hours, and after that, until the next meal time, there would be a scarcity. This would be a very faulty method of nutrition, since most of the tissues are doing as much work at one time of the day as at another, and so need food all the time.

**The Liver as a Storehouse for Carbohydrates.**—To prevent this irregular supply of food to the tissues is one of the duties of the liver. As the food-laden blood passes through it, a large part of the sugar is changed into a compound called **glycogen,** and left stored in the liver cells; Fig. 66. Its chemical make-up is the same as that of vegetable starch. The blood, with a small load of sugar leaves the organ, other food substances having undergone no change. After the food of one meal has been absorbed from the intestine, the liver begins, little by little, to dole out to the blood this stored sugar so that the latter, circulating about the body, contains at all times about the same amount. This uniform supply is necessary for the best health and most efficient activity of the body organs. Too much or too little sugar in the blood is injurious. Thus while the bile secreted by the liver is of little use in digestion, the liver is itself a highly important organ, as a regulator of the food supply to the blood.

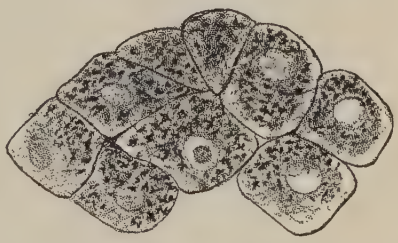


FIG. 66.—LIVER CELLS
Loaded with glycogen which they have made out of sugar taken from the blood. (Modified from Frerichs)

### PATH TAKEN BY THE FATS

The fats pass into the lacteals of the villi and these open into larger vessels in the walls of the intestine, which in turn unite with others to form still larger ones (of about the size of

blood vessels) and then pass up through the mesentery. Thus there are three sets of vessels in the mesentery: arteries bringing blood, veins carrying food-laden blood away, and lacteals carrying off the fat; Fig. 65. The lacteals finally empty into a duct which runs past the liver and stomach, through the diaphragm, up through the thorax into the neck region, a little above the heart. This tube, which is called the **thoracic duct**, finally empties into one of the large veins which bring blood back to the heart; Fig. 65.

The contents of the thoracic duct are white and milky, due to the fat in emulsion; in fact, the contained materials are much the same as the chyle in the intestine. The lacteals, then, and the ducts connected with them act as a temporary storehouse for fats. The flow from the thoracic duct into the large vein at the base of the neck is slow and interrupted and it is only after several hours from the time fat enters the lacteals, that it passes into the main blood system.

The passage of the absorbed fats through the thoracic duct is not produced by any heart-like organ. The simple pressure of the surrounding organs, the peristaltic movements of the intestine, the constant displacement of organs by breathing muscles—these and other lesser influences produce a slow flow. This movement can take place in but one direction on account of valves which open only one way and are located at very frequent intervals throughout the ducts.

Even the fat in time gets into the blood; but it seems as if the thoracic duct and the lacteals were designed to switch the fat around the liver and bring it to the blood without flowing through that organ. The liver can readily store sugars and is not injured by the proteids passing through it, but apparently it is necessary for the fats to reach the blood system by some other course.

## SUMMARY OF DIGESTION AND ABSORPTION

This finishes the story of the entrance of food into the body. The brain begins the history by selecting the food through the sense of taste; heat cooks and prepares it; the teeth grind it into fine pulp which, by means of the tongue, is thoroughly mixed with water and saliva. Then begins a series of chemical changes as the food is passed through that chemical laboratory, the alimentary canal. It is taken into this laboratory as more or less solid material containing proteids, starches, fats and other substances, but by the chemical action of the ferments produced by the glands, these ingredients are softened and completely transformed until they are almost wholly dissolved into a syrupy white mass, which does not bear the slightest resemblance to the original food in appearance, and very little in chemical nature. As the food is forced along, the villi with which the intestine is lined begin to pick out of the mass the useful parts, leaving the rest in the canal to be ejected later as worthless. The sugars and proteids are handed over to the blood vessels which take them to the liver where a part of the sugars is temporarily stored. The fats are passed to the lacteals which likewise carry them to the blood, but by a different track, a side track as it were, which switches them around the liver. Finally all the nutriment gets into the blood by which it is carried around the body to any part that needs it. Digestion and absorption are thus finished and we may turn our attention to the next process—circulation.

## CHAPTER IX

### THE BLOOD AND ITS FUNCTIONS

Blood and blood vessels are entirely lacking in some of the lower animals, as for example, in sponges, jelly fishes, corals and the lowest of the worms, the so-called "flat-worms." In the insects, too, the blood system is present only in a weak, poorly formed way. This seems particularly strange when one considers how dependent a human being is on the blood system; so dependent, indeed, that after a severe cut a person may die from loss of blood. Blood, in fact, is considered the symbol, if not the synonym, of life itself.

By studying these animals, however, we find the reason why they do not need blood systems. The sponge has numerous pores opening into the body; these lead to canals which extend through the substance of the animal, thus carrying all over the body the water and food substances, which enter the canals. At the same time the sponge obtains oxygen from the water circulating through the canals. The jelly-fishes, corals and flat-worms all have complex stomach cavities; numerous pouches and ducts leading away from the stomach carry the food particles to all parts of their bodies. So much water is taken in with their food that these animals obtain all the oxygen they need from the same water in which their food floats. Insects have a tubular digestive tract going almost straight through the animal; but besides this there is a great network of air tubes all over the body, between the muscles, passing into the legs, wings and, in fact, everywhere. These bring air in through sets of pores in the "skin," and take it over the body. In the human being the digestive tract is a tube, with no side branches of any sort; and all the air one takes in goes into two comparatively small sacs, the lungs.

Thus animals in which there is some other means of distributing air and food lack the blood system. We may conclude, then, that one of the functions of that system is the distribution of food and oxygen.

## THE BLOOD

Blood makes up about one-thirteenth of the body weight. It is really a very complex fluid, for it contains all of the food materials from the intestine and also receives many waste products from worn-out parts of the body. But leaving aside these complexities of chemical composition, we may learn by a study with the microscope that fresh blood consists of a liquid almost as limpid as water, which has floating in it an immense number of minute, solid bodies. The liquid is called the **plasma**; the solid bodies are of three kinds: **red corpuscles** or *erythrocytes*, **white corpuscles** or *leucocytes*, and **platelets**; Fig. 10.

The relative proportion of these in the blood is approximately as follows: water 90%, solids 10%. Of the solids, about 72% is proteid in character, the remainder consisting of fats, acids, and salts. Some of these are unutilized food materials, others the result of "wear and tear" of body protoplasm as it ceaselessly, day in and day out, performs its vital work.

**Blood Plasma.**—The plasma is a transparent liquid of a light straw color. It is the plasma that gives the fluid character to the blood and enables it to flow through the vessels. Its chemical composition varies. Into it are absorbed the foods from the intestine, and into it also are passed the various waste products from the body. Its composition will therefore be different after a meal from what it is after a period of fasting. When one is resting, too, fewer waste products are eliminated to make the blood impure than when one is actively working. One of the constituents of the plasma will be noticed later because of its important relation to blood clotting.

This is a proteid known as fibrinogen which is so completely dissolved as to be quite invisible.

**Red Blood Corpuscles.** — Red blood corpuscles are minute discs, having a diameter of about $\frac{1}{3200}$ inch (.007 mm.), and a thickness of $\frac{1}{10000}$ inch (.0025 mm.). There are about 5,000,000 of these in a drop of blood no larger than the head of an ordinary pin. When freshly drawn from the body these lozenge-shaped discs appear concave on each side (Fig. 10), but while circulating in the vessels they are frequently cup-shaped. While, in some respects, they are like other cells in the body they have no nucleus and no power of division. This absence of a nucleus is found only in a group of animals known as *mammals*; i. e. in those which have bodies covered with hair, which suckle their young, and which have distinct thoracic and abdominal cavities separated by a diaphragm. Fishes, frogs, reptiles and birds are not mammals, and their red blood corpuscles are nucleated.

Each corpuscle consists of two parts: (1) a spongy mass, called the **stroma**; (2) a red liquid which is held in this stroma somewhat as water is held in a sponge. The red color of the corpuscle is due to this liquid, which is called **hæmoglobin.** It is the millions of these red corpuscles with their hæmoglobin that give the red color to the blood.

Hæmoglobin is not always of the same color. If it is mixed with plenty of air, it absorbs a great deal of oxygen, becomes a bright, crimson red, and is then spoken of as **oxyhæmoglobin.** This is its condition in the blood in the arteries. If the oxygen is withdrawn, however, the hæmoglobin assumes a darker color, and is called **reduced hæmoglobin.** This is its condition in the blood in the veins returning from the body to the heart. Thus the corpuscles are turned from a dark red to a bright red color as they come in contact with the oxygen of the air in the lungs. This power of absorbing and giving up oxygen is the foundation of respiration and is dependent upon the presence of fresh air. **Hæm-**

oglobin is a proteid, but it differs from most proteids, in that it contains in addition to carbon, hydrogen, oxygen, nitrogen and sulfur, a little iron.

While inside living corpuscles, hæmoglobin is in solution, but if a number of corpuscles are treated with ether and the ether evaporated, hæmoglobin will be left behind in the shape of definitely formed crystals; Fig. 67.

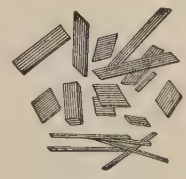


FIG. 67.—CRYSTALS OF HÆMOGLOBIN FROM RED BLOOD CORPUSCLES

It will be easier to comprehend the relation which these corpuscles bear to a person if the facts are stated something as follows: In the blood of a man weighing 150 pounds there are floating about 25,000,000,000,000 red corpuscles. These contain about one and one-half pounds of haemoglobin, and their surfaces equal about 3,827 square yards or the area of a surface 225 feet long by 150 feet wide. (Compare this with the area of your school grounds.) The capillaries in the lungs are so small that these corpuscles pass through them practically in single file. In this way a great area is exposed for the absorption of oxygen.

Where does this great number of red corpuscles come from, and what becomes of them? Do they live as long as the rest of the body, or are they being constantly produced and destroyed? Clearly, there must be some way in which they are constantly produced, for a person may lose much blood from a wound and recover completely in a few days. The answers to these questions are rather unexpected; in a healthy person blood corpuscles are constantly being produced in the red marrow of the bones, and they are being as constantly destroyed in the liver and perhaps in the spleen. Indeed, the bile from the liver is, in part, the waste from broken down red corpuscles. How long a red corpuscle lives we have no means of knowing; but it starts in the bone marrow, does duty as an oxygen carrier for a while, and finally ends its life in the liver or spleen.

**White Blood Corpuscles.**—White blood corpuscles are of a transparent, bluish white color and are considerably larger than the red ones, although the latter are about five hundred times as numerous; Fig. 10. White corpuscles are real cells, since they contain a nucleus, but they are constantly changing their shapes. They are active little bodies which sometimes move of themselves, independently of the blood flow. Any part of the white corpuscle may protrude, and the entire substance of the body be allowed to flow into the protrusion. By repeating this process indefinitely, the corpuscle moves from place to place. This method of locomotion is called **amœboid,** after the amœba, a microscopic animal which moves by the same method.

In function, too, the white corpuscles are different from the red. One of their chief uses is to perform for the body duties similar to those of street cleaners in our cities. They are not confined inside the blood vessels, but may pass out into the tissues, where they have many functions. If any irritating or injurious substance gets into the body under the skin, these white corpuscles collect around it in great numbers for the purpose of removing it. If the irritating substance is small, the white corpuscles may be able to surround it completely and then carry it off to be destroyed elsewhere in the body.

Another useful function of the white corpuscles is to help protect the body against invading disease germs. When these tiny enemies make their entrance, the white corpuscles, or leucocytes, assemble quickly to do battle with them. The corpuscles attack the bacteria, and may even carry off their dead bodies; Fig. 68. Many of the corpuscles, as well as bacteria, are killed, however, and sometimes, indeed, the bacteria overcome the corpuscles. When this occurs, the bacteria spread through the body, and the person "comes down" with the disease. When the corpuscles are victors, and succeed in overcoming the bacteria before they do harm,

one may have absolutely no knowledge that anything unusual has happened in the body. Thus, many a time in our lives, these little defenders have guarded us from dangers about which we knew nothing. Sometimes when this battle is near the surface, the skin becomes painful and inflamed, and later it may burst, allowing pus to escape. This pus is largely made up of white corpuscles; they themselves have died and are discharged, but they first disposed of the foreign germs that would, perhaps, have done us great injury.

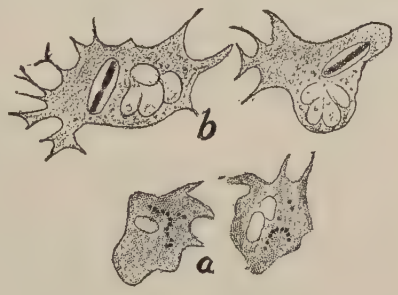



FIG. 68.—WHITE BLOOD CORPUSCLES OR LEUCOCYTES THAT HAVE ENGULFED BACTERIA

In those at *a* may be seen chains of bacteria such as cause blood poisoning and in those at *b* are some rod shaped bacteria. (Metschnikoff)

When leucocytes are exhausted they merely go to pieces and dissolve in the blood, the residue passing out of the body through the different excretory organs.

**Blood Platelets.**—The third kind of solid body in the blood is the platelet. These platelets are ovoid bodies, about one-third the diameter of the red corpuscles, granular but colorless; Fig. 69 *c*. They vary in number but are always very numerous in unshed blood, 600,000 or so in a single drop. These bodies disintegrate very quickly after blood is drawn; so quickly that by the time a drop can be placed under a microscope for the purpose of studying them,

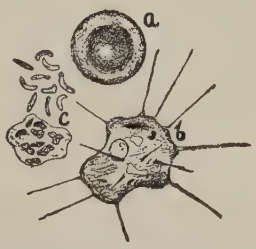



FIG. 69.—VARIOUS BODIES FOUND IN BLOOD

*a*, red corpuscle; *b*, white corpuscle with fibres of fibrin radiating from it; *c*, platelets, both separated and in clusters.

they have entirely disappeared. The only way to see them at all is to draw the blood into some preserving fluid which will prevent them from breaking to pieces. The function of the blood platelets is not definitely known, although they probably have something to do with blood clotting.

## BLOOD CLOTTING

Everyone is familiar with substances which may exist either as liquids or solids. The most familiar example is water, which becomes solid if the temperature falls below the freezing point. The solidifying is dependent on temperature, and the material can be changed from solid to liquid by heating, or from liquid to solid by cooling.

So, too, blood has the property of existing in a liquid and in a solid form. When it becomes solid, we speak of it as **clotted.** This clotting, however, differs decidedly from the freezing of water, since it is not due to cooling, for blood will clot even if kept warm. Indeed, the comparison of clotting with the freezing of water is not a good one, for the blood greatly changes its nature when clotting and can never be brought back again into the condition of liquid blood. If blood is drawn directly from the blood vessels into a small dish, it will be found at first to be fluid, like water; if allowed to stand a few minutes it becomes jelly-like. Presently it forms such a firm jelly that the dish can be turned upside down without displacing any of the blood. If it stands for some time longer the jelly mass will shrink and a yellowish liquid ooze out of it. This liquid is known as **serum,** and the contracted jelly, which holds most of the red corpuscles, is the **clot.** If now the clot is taken out and thoroughly washed in water, all the corpuscles can be separated from it, and the material left will be a tangled mass of white, elastic threads. This substance is called **fibrin.** It must be understood that the fibrin does not exist while the blood is in the vessels, but

is formed while the blood is clotting. Furthermore, it is known that blood does not clot at all unless calcium is present in it.

The agents involved in the production of fibrin, and therefore of clotting, may be shown in relation to one another as follows:

Thrombokinase (from tissue juice, white corpuscles or platelets)
+ Thrombogen (from plasma)
+ Calcium salts (from plasma)
= Thrombin = Fibrin ferment

Thrombin + Fibrinogen (in solution in blood)
= Fibrin (insoluble)

We have already noted that in the blood plasma there is a proteid called fibrinogen (see page 124). This is dissolved in the liquid, and is no more visible than the sugar in a cup of coffee. It is from this fibrinogen that the fibrin is produced. Fibrinogen, however, will not give rise to fibrin if left to itself, but if a certain amount of material called thrombin, or fibrin ferment, is present, it at once breaks up into two substances; one of these remains in solution in the blood, but the other is not soluble, and appears at once as fibres forming the fibrin. Hence blood clotting is due to the formation of fibrin out of fibrinogen under the influence of fibrin ferment.

Whence comes this fibrin ferment? Since the blood will not clot when flowing through the arteries and veins, we conclude that this ferment cannot be present in living blood. It must be formed when the blood is drawn. Its source is not certainly known but there are strong reasons for believing that three different agents are involved:

(a) thrombokinase (from white corpuscles, platelets, or the cut tissues);
(b) thrombogen (from the plasma) and
(c) calcium salts.

When these three factors are present at the same time, blood clots quickly, and thus we conclude that they form the substance which changes fibrinogen into fibrin. At all

events, it is an undisputed fact that while blood is flowing through the vessels, it contains no fibrin ferment, and consequently the fibrinogen remains unchanged; but as soon as the blood comes into contact with any material other than the regular lining of the blood vessels, fibrinogen at once changes to fibrin and the blood clots. Even contact with other tissues, e.g. muscle or skin of the same animal, produces a clot almost immediately; so, too, will an injury to a blood vessel or simple exposure of blood to the air.

At times when it is desired to prevent blood from clotting, this can be done by adding to it certain chemicals, e.g. sodium sulfate or magnesium sulfate, pepsin, trypsin or peptones; the extracts of the salivary glands of leeches or snake's venom will very effectually prevent clotting. Rapid cooling will retard and sometimes entirely check it. Blood can be made to clot more rapidly by bringing it into contact with foreign substances, for example, by covering with cloth a wound from which it is flowing.

**Purpose of Blood Clotting.**—Blood clotting is nature's method of checking the flow of blood from wounds, thus preventing possible fatal consequences. All our lives we are thus guarded, not only from annoyance from small injuries, but from the very serious results which would follow from bad accidents or from surgical operations.

## DISEASES OF THE BLOOD

It is often affirmed that a person's health is poor because his blood is "out of order" or needs "toning up." In most cases, this is a mistake. Health is not determined by the condition of the blood, but on the contrary the state of the blood is determined by the rest of the body. The blood may not be in good condition, it is true, but the reason is usually because the living cells of the rest of the body are out of order. For example, a person is pale and white and suffers from lassitude and other uncomfortable symptoms. The physician,

perhaps, makes an examination of the blood and finds that he has *anæmia,* and that the blood contains too few red corpuscles. Now, while in this case it is true that the trouble shows itself in the blood, the real cause is not there, but in those parts of the body where the red corpuscles are formed, and which for some reason are not making them rapidly enough. Suppose again the paleness to be due to too many white corpuscles. Here too, while the most noticeable feature is in the blood, the real cause is in some of the other organs whose impaired functions result in increasing the numbers of white corpuscles until they are altogether too numerous. The physician's treatment should be directed to the real source of the trouble, not to the blood itself.

**Blood Poisoning.**—Blood poisoning is a name given to a series of troubles caused by a certain kind of bacteria which get into the body and multiply rapidly. The poisoning agents are commonly in the skin, muscles, glands or some other active organ, not often in the blood itself; but in some forms of the disease the blood carries them through the body and hence the name **blood poisoning** arises. The germs which cause the trouble (Fig. 70) are abundant everywhere, in the air, in the soil, on our clothes, on our skin, etc. They do no harm, unless they penetrate the skin by way of a cut or bruise; and even then they do not often cause trouble, for our bodies are wonderfully endowed with power for resisting them. Commonly, therefore, they either do us no injury or produce simply a slight *pimple,* a little *festering sore* or a *boil.* If the body is in good condition, the white corpuscles attack the bacteria in these sores, and with the help of other resisting agencies the germs are destroyed and the sore heals. But in other cases, either where the resistance of the body is very weak or the

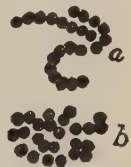



FIG. 70.—THE BACTERIA THAT PRODUCE VARIOUS FORMS OF BLOOD POISONING, BOILS ETC. *a, Streptococci; b, Staphylococci*

germs are very strong, the germs are not checked in their growth, but continue to multiply rapidly and are distributed by the blood, producing serious and even fatal results. Blood poisoning, as we call it, may thus be a very serious matter, but it is similar in nature to the smaller troubles, e.g. festers, boils and the soreness that follows skin wounds.

In endeavoring to avoid all forms of blood poisoning we should remember a few simple facts: (1) The discharges (pus) from sores or boils are sure to contain disease germs and they should by every means be kept from coming in contact with fresh cuts or bruises. (2) Whole, uninjured skin is a sufficient protection for the parts underneath and germs cannot penetrate it. But *all points where the skin is broken, cuts and bruises, should be carefully cleansed in boiled water.* (3) Various disinfecting ointments contain substances which kill the germs. These ointments are of extreme value in cases where the skin is broken. A *wash of carbolic acid, one part to twenty of water,* is an excellent one to keep on hand, and to use freely for washing all cuts, bruises or deep scratches.

**Malaria.—Malaria, chills and fever,** and **fever and ague** are all practically the same disease. Here we have an actual disease of the blood, for it is due to a minute parasite that lives upon the red corpuscles and in no other part of the body. These parasites kill the corpuscle, which then breaks to pieces, and the parasites come out into the blood plasma. At this time, a little poison is let out into the blood from the broken corpuscle, producing a chill, followed by a fever. Soon after, the parasites attack other corpuscles, grow forty-eight hours and break up again. Thus, this peculiar disease is *intermittent;* i.e. comes with regularity at certain intervals. If there is a small amount of quinine in the blood at the time the corpuscles break up, the little parasites will be destroyed and the disease checked. Hence quinine is almost always used as a medicine in cases of malaria.

One of the most valuable discoveries of science has been

the method by which these little parasites find their way into the blood. They cannot pass directly from person to person and hence the disease is not contagious. It used to be supposed that malaria came from bad air, especially from the air of swamps, night air being thought particularly dangerous.

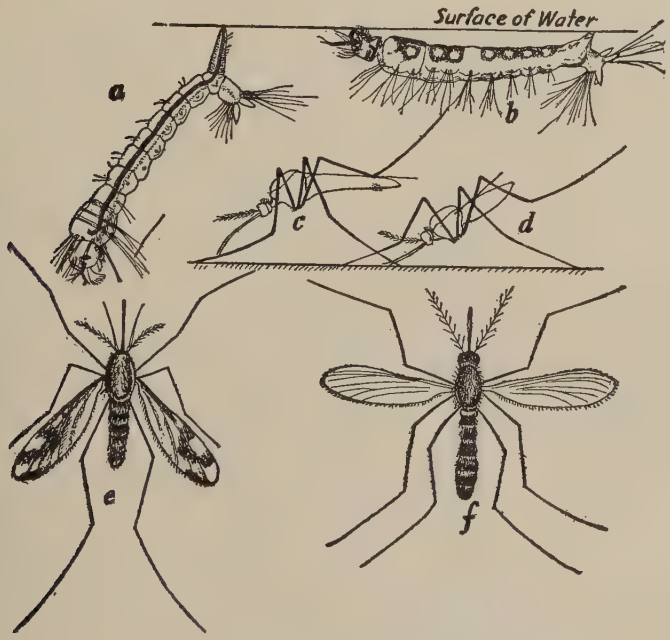



FIG. 71.—MOSQUITOES

Figures *a* and *b* show the larvæ in water, *a* being the harmless species (Culex) and *b* (Anopheles) the species that carries malaria. At *c* is shown the position assumed by the harmless type upon alighting, and at *d* the position of the dangerous one. In the latter it will be seen that the body and head are in one straight line while in the harmless species the body is bent at the neck. At *e* is shown the dangerous Anopheles with spotted wings and five hair-like projections (or feelers) in front; at *f* the Culex with plain wings and three feelers.

But these theories have been disproved. It has been found that these parasites live in a certain kind of mosquito. If

a female mosquito bites a patient suffering from malaria it will suck some of the red corpuscles containing the parasites into its body. In the mosquito these parasites go through some changes and finally come to lodge near its mouth. If this mosquito later bites another person, the tiny parasites are likely to be inoculated into the body where the skin is pierced. Thus a second person is infected. This is the only method by which malaria is known to be distributed. Hence any means of getting rid of mosquitoes is a protection against malaria. Mosquito netting at windows and doors is a very efficient protection from this disease. Draining puddles and pools and emptying all barrels of standing water where mosquitoes breed is another. Only one kind of mosquito distributes the disease and fortunately this is not the most common kind. A method of distinguishing it from the harmless species is explained in Figures 71 and 72.

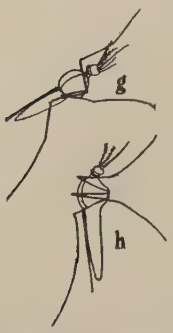



FIG. 72.—MOSQUITOES
*g*, Anopheles, *h*, Culex, as they alight on the walls of a room.

**Yellow Fever.**—Yellow fever is fortunately uncommon in this country, occurring only at rare intervals in the southern states. In tropical countries, e.g. South America and the West Indies, it is of more frequent occurrence. Occasionally it does get into our southern cities in the summer, and in past years it has produced very serious epidemics with thousands of deaths. Its cause has recently been discovered to be an extremely minute unicellular organism. It is mentioned here because, like malaria, it is known to be distributed by mosquitoes, though the species carrying yellow fever germs, Stegomyia, is not the same as the one which spreads malaria.

These facts show clearly that mosquitoes are among our most deadly enemies. The different states of the Union are showing appreciation of this fact by appropriating con-

siderable money for the warfare against mosquitoes. Since mosquitoes breed in stagnant water, the draining of such breeding pools or the pouring of kerosene on the surface is an efficient method of killing the young. Everyone for his own good, as well as for the good of others, should give all the assistance he can to this work of mosquito extermination.

**Influenza.**—While this disease is doubtless acquired by breathing in the organisms causing it, it manifests itself primarily as a disturbance of the blood in the form of a fever. As is well known, it is extremely contagious, and thus easily assumes the proportions of an epidemic. It differs from an ordinary cold by spreading even more rapidly, in causing a person to feel suddenly weak, experience pain in the head, back or eyes, develop a fever and "feel sick" to a greater degree. As to its cause, several bacteria have been recognized as present, and the practice of inoculation against the disease has been begun with fairly successful results. However, immunity is very transitory, and one may "catch" influenza repeatedly. Fatal results seldom accompany the malady by itself, but it leaves the system weakened and susceptible, so that other more serious diseases, *e.g.* pneumonia, are very liable to follow. Extreme care while convalescing should be observed.

Influenza is doubtless spread by the "droplet method;" *i.e.* a healthy person breathes in minute moisture droplets, containing the germs, which have been expelled by a sick or near-sick person while sneezing, coughing, talking, or singing. One should avoid crowded rooms, cars, public gatherings of all kinds, and contact with the sick; also spend as much time as possible in the open air in recreative exercise. If attending those sick with influenza, one should always wear a gauze cloth over the nose and mouth as a precaution.

## CHAPTER X

## THE HEART AND THE BLOOD VESSELS

The heart has been recognized as an important organ for a longer time than any other part of the body, and numerous phrases in literature show the fanciful, as well as mistaken, ideas once held concerning its function. The expression "love with all one's heart" is an example of the erroneous notion that the heart has something to do with the emotions. In reality the heart has but one function: it simply pumps the blood.

**Location of the Heart.**—The heart is located in the thorax, between the lungs, just a little to the left of the mid-line, and back of the "breast bone." The rigidity of this bone prevents one's feeling the heart under it, but the lower end of it produces a distinct "beat" which can be felt and seen between the fifth and sixth ribs. It is swung freely in the thoracic cavity, attached to its upper wall by masses of connective tissue, which also bind it to the large arteries and veins, and to the windpipe.

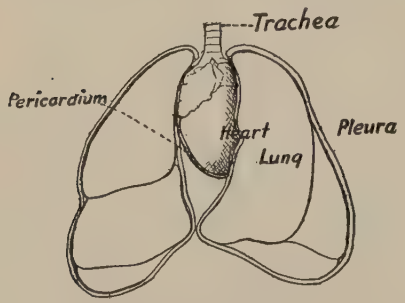



FIG. 73.—DIAGRAM
Showing the relations of heart, lungs and membranes around them.

**The Coverings and Structure of the Heart.**—The heart is completely enveloped by a two-layered bag, the **pericardium** (Fig. 73), which is pierced only by the large arteries and veins leaving and entering the organ. The inner layer of the pericardium is grown fast to the heart muscle, and thus forms a firm, tough covering for it; the

outer layer is loose, the two moving freely over each other. These pericardial layers are covered by glandular epithelium which secretes a fluid into the space between them, this liquid being naturally called the **pericardial fluid.** Were it not for this fluid, the ever-moving heart would rub against the surrounding tissues, producing much friction and inflammation.

A person's heart is about the size of his fist. In shape it is something like a strawberry and lies with the small end, or apex, pointing downward and toward the left; the upper end is called the base and here the large arteries leave and the veins enter it. It is a hollow organ, the walls of which are composed mainly of muscle; on the outside more or less fat is usually deposited, especially in certain depressions where the arteries and veins emerge, and along grooves which extend lengthwise or obliquely on the organ over places where partitions run in the interior.

The cavity of the heart is divided by a vertical wall into right and left chambers; and each of these is again partially divided into an upper portion, **the auricle,** and a lower, the **ventricle.** Each of these four chambers is lined with a smooth glistening sheet of membranous epithelium, which keeps the blood from direct contact with the muscle tissues of its walls. The walls of the auricles are very much thinner than those of the ventricles and the wall of the left ventricle is thicker than that of the right.

### THE EVENTS OF A HEART BEAT

We can best learn the structure and action of the heart if we trace the flow of blood through it, noticing how the valves are closed and opened so that the blood always flows onward. The blood is brought from the body to the heart through two large veins, which open into the right auricle—the **superior vena cava,** bringing the blood from the upper part of the body, and the other, the **inferior vena cava**, bringing it from the

lower part; Fig. 74. If we begin our description at the rest period of the heart, i.e. the period between any two beats, we shall find that the blood flowing in these veins passes in a large

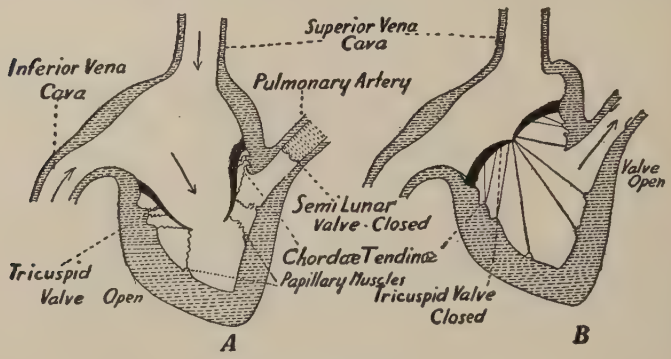



FIG. 74.—DIAGRAM

Showing the mechanism of the heart. At *A* is shown the right side of the heart at the period of rest, and at *B* the arrangement of the valves when the heart contracts. The arrows show the direction of the blood flow.

stream directly into the right auricle (Fig. 74), whence it flows freely through the wide opening from the auricle into the ventricle. Thus the auricle and ventricle are both filling at the same time.

The opening between the right auricle and right ventricle is guarded by three flap-like membranes, attached at the top of the ventricle; when the ventricle is empty, they hang down loosely (Fig. 74 *A*), but as the entering blood collects in the bottom, these flaps float on its surface. This condition lasts only for a fraction of a second, when the muscles in the walls of the auricle contract, forcing all the blood into the ventricle with a rush. Carrying the flaps on its surface, the blood rises rapidly until the ventricle is completely filled. At this time the valves are lifted up directly across the opening from the auricle; Fig. 74 *B*. They are of such size and shape that when in this position they exactly fill the opening, completely

preventing the passage of any blood back into the auricle. These valves between the chambers of the right side of the heart are called the **tricuspid valves.**

Next, the muscles in the walls of the ventricle contract, pressing upon the blood until the ventricle is emptied. In what direction will the blood flow? It would go back into the auricle if the tricuspid valve had not closed the opening in that direction. These valves are only soft membranes, and one would suppose that they might give way under the pressure of blood in the ventricle and turn back into the auricle. To prevent this, stout cords (**chordæ tendinæ**) are attached to the edges of the valves (Fig. 74), their other ends being fastened below to the walls of the ventricle. These cords are of such lengths that when the valves are stretched across the opening the cords are tight; Fig. 74 *B*. It would not be possible to push the valves up into the auricle without breaking these cords; moreover they can be drawn downward somewhat by little muscles attached to their lower ends, the so-called **papillary muscles.** As the ventricle contracts. then, the blood must find another outlet.

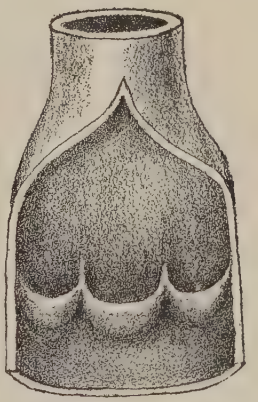


FIG. 75.—THE PULMONARY ARTERY CUT OPEN TO SHOW THE SEMILUNAR VALVES.

The only real outlet from the right ventricle is a large artery shown in Figure 74, and called the **pulmonary artery,** since it leads to the lungs. This artery is already filled with blood, also under pressure, blood that would readily flow back into the heart were it not for a set of valves preventing such a return; these, called the **semilunar valves,** consist of three soft folds in the shape of half-cups or pockets with their open ends directed away from the cavity

of the ventricle; Figs. 74 and 75. When the blood in the pulmonary artery starts to run back into the empty ventricle, it fills these little cups, causing them to swell until the three stretch completely across the lumen of the artery, thus wholly blocking the passage and preventing any backward flow of blood. But when the ventricle contracts, blood is pushed against the cups from below until it finally flattens them against the walls of the artery so that blood can pass them easily. These cup-like flaps remain flattened against the walls of the pulmonary vessel as long as the contraction of the ventricle forces the blood onward.

After the ventricle has contracted as much as it can and has squeezed out practically all the blood it contained, the muscles in its walls relax, leaving the cavity free to fill once more. The blood which has just been forced into the artery starts to flow back but immediately fills the semilunar valves, which then block its backward passage. This action can be better understood, if compared to the behavior of an umbrella in a wind. When pointing into the wind it offers little or no resistance to the currents of air, which would tend to close it; but if turned the other way, it is immediately opened and filled, thus blocking the passage of the wind. The blood cannot flow back into the ventricle but as the ventricle relaxes, the tricuspid valves fall down loosely into the ventricle again, thus allowing more blood to enter it from the auricle and reinstating the condition with which we started.

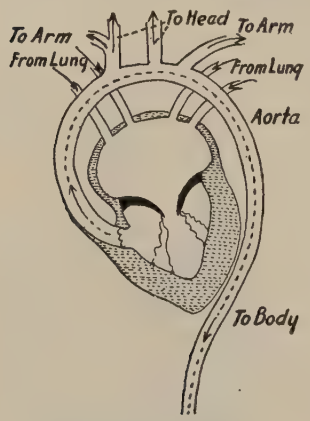



FIG. 76.—DIAGRAM
Showing the veins entering and the arteries leaving the left side of the heart. Broken line marks the aorta.

The blood that flows out of the right ventricle goes through the pulmonary artery to the lungs, whence it goes through four vessels called the **pulmonary veins** to the left auricle of the heart; Fig. 76. The left side of the heart, which the blood now enters, is almost exactly like the right side; there is a similar flap-like valve hanging down between the auricle and ventricle. This **mitral valve** has two flaps instead of three, but its action is precisely the same as that of the tricuspid. A large artery also leads out of the left ventricle, its opening guarded by three semilunar valves, exactly like those at the origin of the pulmonary artery. This artery into which blood is pumped by the left ventricle is called the **aorta,** and through branches of it, as we shall see, blood is distributed over the entire body.

**Rate of Heart Action**[1].—The beat of the heart is really very rapid, a whole beat occupying less than a single second. About seventy times a minute, day and night, the heart goes through the entire act of opening and closing its several valves and forcing along the blood. The two sides beat at exactly the same time, so that with each beat a small cupful of blood is forced into the pulmonary artery from the right ventricle and a similar amount from the left ventricle into the aorta. The actual beat of the heart, i. e. the contraction of the muscles to force the blood along, takes only about 0.3 of a second. After the beat, the heart rests during the time that the auricles are filling from the veins. This time, which is the only rest the heart has from its continual work, is about 0.5 of a second. The beating period is called the **systole,** and the resting period, the **diastole.**

**Heart Sounds.**—If one places his ear over a person's heart when it is beating normally, or if an instrument constructed for the purpose (the stethoscope) is applied to the area above the heart, each beat seems to be accompanied by two sounds, one longer than the other. When a heart beat begins and the

blood rushes into the ventricle from the auricle, the curtain-like valves lie in line with the current, just as a flag flies out in the current of the wind. Although the wind may be steady, the flag "flaps" from side to side. So, in the heart, we can imagine the mitral and tricuspid valves wavering in the current of blood, even if it is steady. This is thought to be the cause of the first sound.

The second sound, following closely on the first, is sharper and shorter. It is believed to be caused by the closing of the semilunar valves in the large outgoing arteries. These, it is thought, are thrown into their tense, filled condition so suddenly that they give rise to a distinct impact and noise, just as doors do when they suddenly close in a current of wind, even though they may be fitted with appliances for preventing their actual "slamming."

**The Throb at the Breast, and the Pulse.**—When the heart beats, the apex is turned distinctly forward with sufficient force to lift the body wall between the fifth and sixth ribs, and at this point a throb is easily felt. Every time the heart beats a small amount of blood is forced into the arteries. This fills those near the heart more full of blood than elsewhere; consequently a wave of pressure travels rapidly along, causing a slight swelling of the arteries on its way. If the fingers be placed on the artery of the wrist, where it comes near the surface, this wave can be felt, and is called the **pulse**. The pulse is due to a temporary increase in the diameter of the artery, and is not as it seems to be, a little jet of blood flowing through the artery at the point where the pulse is felt. The pulse can be felt in any of the arteries which come near the surface; but as arteries are commonly deeply imbedded in the muscles, there are only a few places aside from the wrist where it is evident, e. g. the neck, and about the temple, back of the eye. By feeling the pulse a physician can determine the rate of the heart beat as well as its force. The normal rate is 72 per minute.

The heart action, however, undergoes an interesting change of rate with age, the average rate found in large numbers of instances being as follows: In early babyhood, 140 beats per minute. In childhood, 100 per minute. In youth, 90 per minute. In adults, 75 per minute. In elderly persons, 70 per minute. In very aged persons, 75 to 80 per minute.

**The Work Done by the Heart.**—The muscular power of the heart is very great. The work it does during one day is about equal to the additional energy expended by a man in climbing to the top of a mountain 3600 feet high. Assuming that the man weighs about 150 pounds, this would be equal to an amount of energy sufficient to lift 90 tons to a height of three feet. The work of the left side is greater than that of the right, since the former has to drive the blood all over the body, while the latter has only to force it through the lungs which are near by. For this reason the muscle walls of the right are much thinner than those of the left ventricle.

**Defects in the Heart Mechanism.**—We can readily see how a very slight injury to the heart might result seriously. Suppose, for example, that the valves should fail to close the passages over which they are placed as guards. In some cases of heart disease, a bit of clotted blood collects on the edges of the valves, preventing their perfect closure, causing a leakage and seriously interfering with the action of the heart. It appears that the serious disease, influenza, may frequently affect the heart muscles and valves, causing faulty action and thus menace the general health. But one must not think that, because he has a pain around the heart, he is suffering from heart disease. Indeed, it often happens that those who have some defect in the heart mechanism are quite unconscious of the fact, since the effects are generally more noticeable elsewhere.

## CAUSE AND REGULATION OF HEART BEAT

What makes the heart beat? No one as yet understands life sufficiently to give a satisfactory answer to this question, but we do know that most activities are brought about at the command of the brain; most of the muscles will not contract at all unless it orders them to do so. How is it with the heart? Does it need orders from the brain or can it direct its own beating? That it can act independently of the brain has been shown in the instances of many animals, where the heart has been entirely removed from the body and has yet continued to beat for a considerable length of time, even so long as two days. Evidently then, the heart contains in itself some agency that causes it to beat.

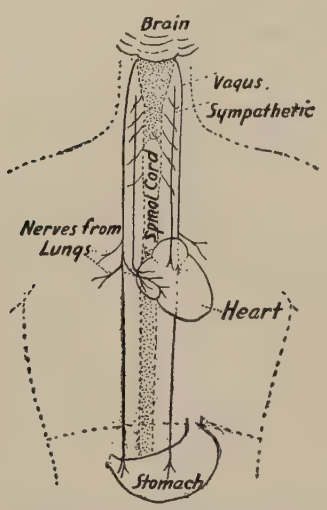



FIG. 77.—DIAGRAM
Showing the nerves controlling heart beat.

The heart is thus *automatic* and would of itself continue to beat regularly through life; but such regularity would be very unsatisfactory, for the amount of blood which the working organs need varies at different times. When the muscles are active they need much blood, when they are quiet they need little. When one is asleep, the organs need less blood than when he is awake, and all through life occasions are constantly occurring where the body demands a more or less rapid circulation of blood than usual. To meet these varying demands, the brain has the power of *regulating the heart beat.*

Two sets of nerves pass to the heart; one set arises in the medulla of the brain, the other in the sympathetic

nervous system. The nerves from the brain, the **vagi** (Fig. 77), act as a brake on the heart; if they are artificially stimulated, the beat of the heart is retarded; or if they are severely irritated, heart action may stop altogether for a short time, although after a little the heart escapes from its influence and goes on beating again. The office, then, of the vagus nerves is to keep the heart from beating too rapidly. In a healthy body they would never stop the action as described above, but the slowing influence is necessary when the body tissues need but little blood, as when one is idle or asleep. The vagus nerves, because they check the heart action, are called the **inhibitor nerves.**

The second pair of nerves which affect the heart are called the **sympathetic nerves;** Fig. 77. If these nerves are stimulated, they make the heart beat faster and more forcibly, for which reason they are sometimes called the **accelerator nerves.**

Thus we find that three influences are constantly affecting and regulating the heart:

1. The impulse to beat, located within the heart itself.

2. The inhibitory influences, which reach it from the central nervous system over the vagus nerves.

3. The accelerator influences, which come over fibres by way of the sympathetic nerves.

All these actions take place unconsciously, for one has no power voluntarily to modify the activity of the heart. If the heart is thus made to beat more or less rapidly, it, of course, affects the rate of circulation. The more rapidly the heart beats, the more rapidly the blood circulates, and a slowing of the heart beat will check the circulation of the blood.

## THE BLOOD VESSELS

All vessels in the body which conduct blood, "pure" or "impure," away from the heart are called **arteries;** all which carry blood to or toward the heart are called **veins.** Both are large in the region of the heart; but if one follows the ar-

teries away from the heart, he finds that they branch repeatedly until at the ends of the arms, in the head, skin or intestine, they are extremely small. The smallest subdivisions of the blood vessels are called **capillaries.** Soon these minute tubes unite as veins, which as they go toward the heart are joined by others and finally are even larger than the arteries.

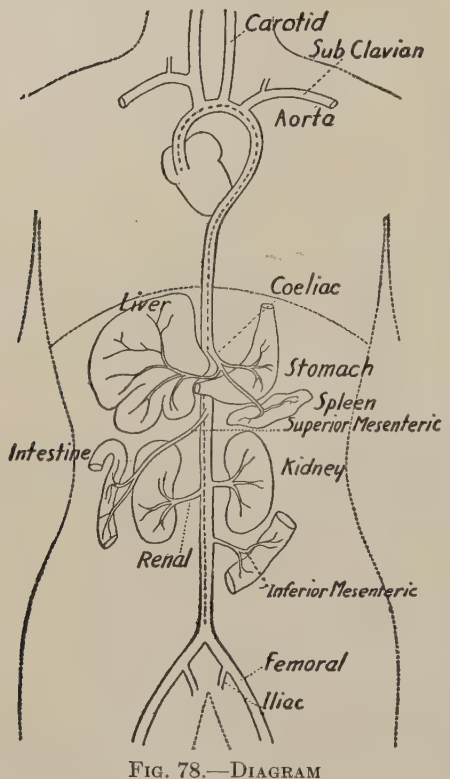



FIG. 78.—DIAGRAM
Showing the aorta and its chief branches. The broken line runs through the middle of the aorta.

**The Arteries.**—From the right ventricle, the blood enters the **pulmonary artery;** Fig. 74. This artery divides, sending one branch to each lung, and inside the lungs each branch divides into numerous smaller branches; finally, each minute twig breaks up into a profusion of lung capillaries. In these capillaries the blood takes up and gives off gases. After passing through the capillaries, the blood collects in veins which unite to form large trunks, that finally leave the lungs, going immediately into the left auricle; Fig. 76. From here, the blood goes to the left ventricle, and thence out through an artery, the **aorta:** Fig. 76.

Almost before this aorta emerges from the base of the heart, it gives off two small arteries which supply blood to the heart muscle itself. It may seem strange that the heart with the great stream of blood flowing through it needs special arteries to supply it with blood. But the blood flowing through the heart does not nourish it any more than the sap running up the tree nourishes the outer layers of the bark. Hence the heart, which works more constantly than any other organ, needs its own blood supply, which is received through these **coronary arteries.**

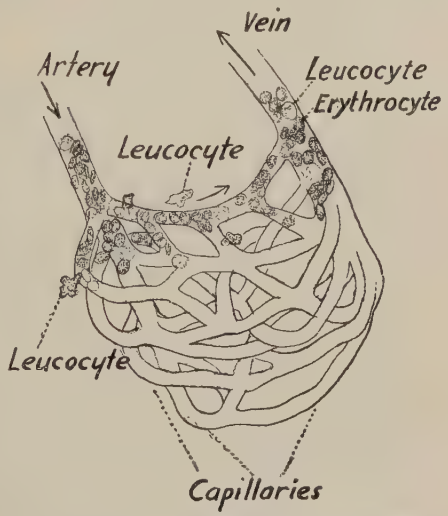



FIG. 79.—THE TERMINUS OF AN ARTERY
Showing its connection with a vein through the capillaries. In the upper capillaries are shown blood corpuscles flowing through them. Some leucocytes are shown making their way through the capillary walls, and others quite outside of the blood vessels.

The aorta goes upward a couple of inches, bends toward the left, and then turns downward through the thorax and abdomen, to the lower part of the body, as shown in Figure 78. Before turning downward it gives off branches, of which the **carotids** pass to the head on each side (Fig. 78); while others, the **subclavians,** pass to each arm, thus supplying the upper extremities with blood. The right carotid and right subclavian leave the aorta as one trunk that soon divides. The main artery (aorta) descends through the abdomen, side branches furnish blood to the intestine and other organs in the abdomen, and finally the aorta divides, one branch extending into each leg.

The chief arteries and the organs to which they go are diagrammatically shown in Figure 78.

**The Capillaries.**[1]—Each artery divides and sub-divides into smaller and smaller branches, and the smallest twigs are distributed to the tissues in every part of the body. If we follow a single one of these branches, we find that each ultimate twig finally breaks up into a profusion of extremely minute vessels, the capillaries, too small to be seen with the naked eye; Fig. 79. They branch abundantly and unite in the form of a network, so that the blood which flows into them has no definite course but may go through the network in any direction. These capillaries (Fig. 80.) are of great importance, for it is through them that the blood gives up its nutriment to the tissues and takes in turn the waste materials which may have collected in them.

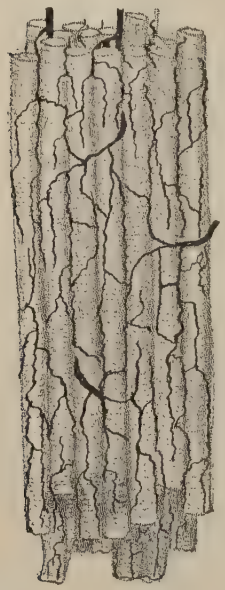


FIG. 80.—SHOWING THE DISTRIBUTION OF CAPILLARIES IN MUSCLES

The black irregular lines are the capillaries. Their minuteness and abundance may be inferred from the fact that the muscle fibres themselves are only about one five-hundredth of an inch in diameter.

**The Veins.**—After passing through the capillaries the blood collects in vessels, called **veins.** The smallest of these join others from other sets of capillaries until they soon become vessels of good size. Every artery ends in a set of capillaries, and each set of capillaries empties into minute veins which unite with others to form main trunks, carrying the blood back toward the heart. The blood from the head returns in two large veins on each side of the neck, known as the **jugular veins** (Fig. 81), and these join the large veins coming from each

[1]See Demonstration, Appendix, Section 14.

arm to form two trunks, which finally unite, forming one large vessel, the **superior vena cava**; Fig. 81. This empties directly into the top of the right auricle, as we have already noticed. The blood from the lower part of the body unites in large veins, finally forming one great trunk, the **inferior vena cava** (Figs. 65 and 81), which also empties into the right auricle. By these two large veins all of the blood carried out from the left ventricle, after passing through an immense system of capillaries, is brought back to the right ventricle to be sent once more to the lungs. In general, one may say that the blood vessels near the surface of the body are veins, while the arteries are imbedded deeply in the tissue; hence the wounding of the flesh is almost sure to cut a vein, but will not, unless very deep, injure an artery.

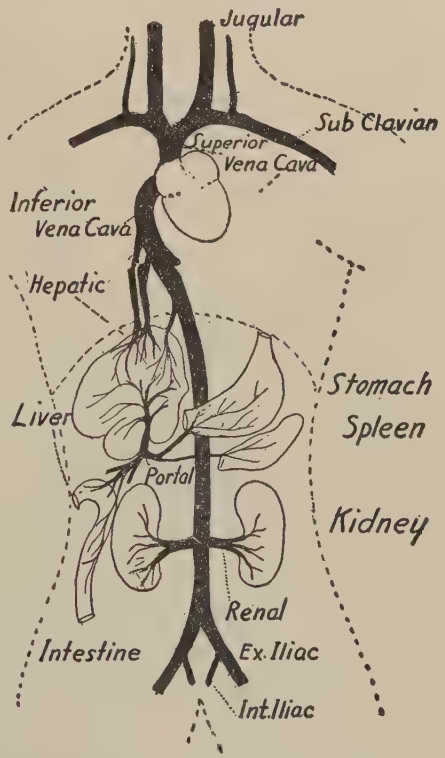



FIG. 81.—DIAGRAM
Showing the course of the chief veins.

As a rule the arteries and veins going to and from a given area or organ lie closely parallel to one another, and often have the same names, *e. g.* subclavian artery, subclavian vein.

**The Portal Blood System.**—The portal blood system has already been fully described (see page 118). Briefly summarized, the portal vein begins in the capillaries of the intestine, stomach and spleen; the blood from all these organs runs together to form the portal vein proper, which enters the liver and there breaks up into capillaries, for purposes already mentioned (shown also in Fig. 81). The liver, then, receives venous blood from the portal vein, and arterial blood from a branch of the aorta as it runs down through the abdomen.

## GENERAL SUMMARY OF THE CIRCULATION

The circulation of the blood is a double one, one half going from the right ventricle through the lungs and back to the left ventricle; the other half from the left ventricle through the body and back to the right ventricle. The circulation through the lungs is called the **pulmonary circulation**; that through the rest of the body is the **systemic circulation.** During its entire passage around the body the blood as blood never leaves the arteries, capillaries and veins (except in the spleen). Remembering that the right and left sides of the heart are entirely separated, it is plain that the blood after leaving the left ventricle of the heart, traverses the body, returns to the right side of the heart, goes thence to the lungs and so finally returns to the left side of the heart whence it started. It has however traversed no area twice even though it has been twice to the heart.

## STRUCTURE OF BLOOD VESSELS

If an artery be taken from an animal's body it will be found that it is not a limp tube, but rigid enough to keep its shape even when empty. The tissues which make up an artery are arranged in three chief layers; Fig. 82. Next to the cavity

of the tube is a layer of thin, flat cells, making up a so-called **lining epithelium**; outside this is a middle layer of involuntary, **smooth muscle,** the fibres of which pass around the tube; the outer coating is made of **connective tissue** disposed in a dense, spongy mass of elastic fibres which thus gives the tube its rigidity. If an artery is stretched it will return to its normal length like a strip of rubber; if it is closed at one end and air forced into the other, the artery will swell to two or three times its first diameter, but will return to its normal size when the pressure is relieved.

Agents commonly causing the contraction and relaxation of these muscles are discussed on pages 162-163.

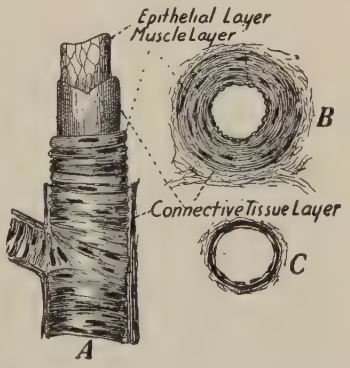



FIG. 82.—SHOWING THE STRUCTURE OF A BLOOD VESSEL.
At *A* is shown an artery with the different layers removed at different levels. At *B* is a cross section of an artery, and at *C* of a vein. (Modified from Landois.)

**Veins** are made of the same tissues as arteries; they differ in that the walls are very much thinner so that the tube collapses whenever it is empty. The muscle and connective tissue coats cannot be easily distinguished as their fibres are mixed together, and both are thin as compared with the same layers in arteries; Fig. 82 C. Veins are much less elastic as well as less rigid than arteries. Some veins are also provided with **valves** which prevent the blood from flowing in any direction except toward the heart. These valves are made of a thin, flexible layer of connective tissue and epithelium in the shape of half cups, fastened to the walls of the veins by their edges; Fig. 83. Thus when the blood flows in one direction the valves flatten against the side of the tube and offer very little resistance; but if the blood starts back

ward in the other direction, they fill and thus occupy the whole calibre of the vein.

**Capillaries** are delicate, thin-walled tubes made of cells which are continuous with the lining epithelium of the arteries and veins; Fig. 84. The capillaries are essentially the same as the arteries with the muscle and connective tissue layers absent. Through their thin walls the fluids of the blood easily pass, and thus come in contact with the surrounding tissues. In size, capillaries are, on the average, about $\frac{1}{2500}$ of an inch in diameter, and their numbers are countless. The finest needle cannot pass through the skin without puncturing some of them, and the deeper lying organs are supplied in the same way as those on the surface.

FIG. 83.—A VEIN CUT OPEN
To show the irregular valves within.

FIG. 84.—A BIT OF A CAPILLARY
Showing it to be made of a single layer of epithelial cells only.

Each of these blood tubes, then, is especially fitted to its place and function; the arteries withstand the powerful, unremitting driving of blood into them by the heart; the capillaries allow the passage of the nutrient fluids and gases into the surrounding tissues, and also take up waste fluids and gases; the veins conduct blood back to the heart, open to their full diameter all the time to permit the easy flow of blood, yet collapsible so as to prevent any tendency to the formation of empty spaces. Of course, blood will not tend to flow

backward through the arteries since the heart pump is constantly pushing more blood along into them, thus keeping the stream in one direction. Veins, however, which do not feel this impulse from the heart, are provided with valves so that a forward flow alone is possible.

**Diseases of the Circulation.**— Anything that impairs the circulation will evidently interfere with normal bodily activity. Irregularities in the action of the valves or muscles of the heart will of course interfere with circulation. Slight imperfections in heart action are not uncommon. They are commonly first noticed by a shortness of breath rather than any trouble around the heart. Persons with such defects must live a more quiet life than is necessary for one whose heart is normal, and must avoid all forms of athletics that produce excessive strain or exhaustion, e.g. running or football. With care in regard to overstrain, these heart weaknesses need not cause especial alarm, and those who have them are likely to live as long and useful lives as others without such weakness.

In youth all the arteries are strong and elastic and capable of adapting themselves to a large range of needs, so that vigorous exercise, even of long distance running, is well endured. When one passes middle life, however, the arteries become less elastic and less able to respond to unusual demands upon them. When this occurs a person should begin to live a more quiet life and not subject his heart and arteries to such strains as would come from running to catch a train, hurrying up stairs, or other vigorous exercise. Later in life the trouble may become excessive, producing a disease called hardening of the arteries (*arterial sclerosis*). This is commonly a sign of the approach of old age and for it there is no known remedy.

## CHAPTER XI

## THE CIRCULATION OF THE BLOOD AND OF THE LYMPH

Nearly every one has seen firemen handling hose, and has noticed how, as the engine pumped, water spurted out at the couplings or at some leak in the hose, showing that it was under great pressure. This pressure is due both to the steady pumping of the engine and to the small nozzle at the end of the hose. If the nozzle were taken off, the water would run in a large stream but would not be thrown any great distance, as there would be nothing to prevent the whole pipeful from escaping as fast as the water was pumped into the hose. In such a case the water would be under little or no pressure; Fig. 85.

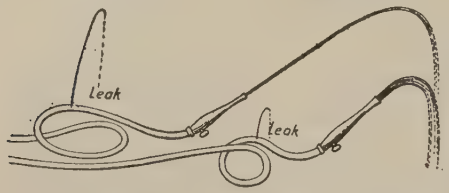



FIG. 85.—SHOWING THE EFFECT UPON PRESSURE OF DIFFERENT-SIZED NOZZLES
There is a leak in each hose and the height of the stream of water shows the pressure.

### BLOOD PRESSURE AND ITS CAUSE

The blood in our arteries is under pressure for similar reasons, and the pressure is produced by two similar factors, (1) *the heart beat*, and (2) *the resistance* offered by the capillaries to onward flow. Since the heart contracts about seventy times a minute and pushes fresh blood into the aorta, the influence of its beat is evident. The narrower arteries and capillaries offer great resistance to the blood flow, corre-

sponding roughly to the nozzle of the fireman's hose. When a large artery is wounded, the force with which the blood comes from the cut strikingly shows this pressure.

Naturally, the blood in all persons is under some pressure no matter what their age. Age makes much difference, however, and it has been found that in boys and girls of ten years of age the pressure is only about one-half what it is at twenty-five years and again that, in persons of fifty, it is about eighteen per cent more than at twenty-five. Much of this is explained by the decreasing elasticity of the arteries as one grows older.

In the aorta near the heart the pressure is very considerable, but it is slight where the blood flows into the capillaries. It will be remembered that the capillary walls are very thin, only the thickness of one cell for the most part; and this condition, which is necessary for the ready exchange of materials through their walls, would make it impossible for them to resist high pressure.

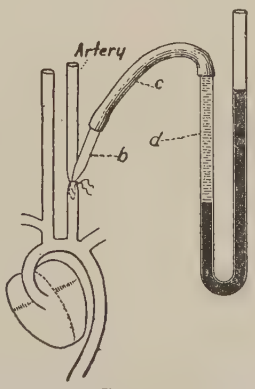



FIG. 86.—SHOWING METHOD OF MEASURING BLOOD PRESSURE

At *b* is a glass tube tied within an artery of some animal; *c*, a flexible rubber tube; *d*, a glass tube containing mercury. The greater height of the mercury in the open arm of the tube shows the pressure.

An idea of the amount of pressure in the arteries has sometimes been gained in the following way. If a glass U-tube be inserted into a large artery in the neck (Fig. 86) and if this tube be open at the end, the blood will, of course, flow out under its pressure. But if the tube be placed in a vertical position and mercury be put into it to hold the blood back, the more forcibly the blood presses, the more mercury will be required to hold it back and keep it from rising and coming out. It takes about nine inches of mercury in the tube to prevent the blood from rising. For this reason we

say that the pressure of blood in the artery is nine inches of mercury. The pressure varies a little with each heart beat, being greatest while the heart is contracting and least when the heart is resting. The pressure decreases as the arteries become smaller until it becomes very slight in the capillaries. This should naturally be so, for, as seen on page 152, capillary walls are extremely thin, and slight pressure would rupture them. That they possess some elasticity, however, is evident from the appearance of the face when blushing; it is also known that the lymph passes through the walls of capillaries, sometimes rapidly, sometimes slowly, and this seems to be due to a varying pressure within them as well as to a varying permeability of capillary walls.

With the veins, into which the blood flows from the capillaries, the conditions are very different. They are wide open where they end at the heart, so that there is nothing to keep the blood from flowing freely until it reaches that organ. There is nothing corresponding to the nozzle of the hose. For these reasons the blood in the veins is under much less pressure than that in the arteries, and varies much with the location and position of the organ.

**Bleeding from Arteries and Veins.**—If an artery is cut, the blood will come out in forcible jets, and prompt action is necessary to prevent the person from bleeding to death. The bleeding must be stopped by compressing the artery between the cut and the heart. Such accidents are most common in the legs and arms where they can easily be treated. Figures 87, 88 and 89 show the course of the chief arteries in an arm and leg. The easiest and most effectual way to stop bleeding is to put a ligature above the wound. A doctor should be summoned and the ligature kept in position till he arrives.

Wounds in veins are generally less serious than in arteries, but should a large vein be cut and the bleeding be so rapid that clotting will not stop it, a ligature should be placed beyond the wound.

**The Pulse.**—In an earlier section the real cause of the pulse, i.e. the constantly alternating increase and decrease in size of the arteries due to heart beat, has been noted. There is, however, no pulse in the capillaries. Such a constant stretching and swelling would break down their thin walls. In the veins, too, since they are formed by the running together of the capillaries, no pulse is present. Two agents have brought about this disappearance of pulse in the veins, (1) the elasticity of the arterial walls, and (2) the opposition which the small arteries—arterioles—offer to onward blood flow. If the arteries had rigid walls, there would be pulse in the capillaries and veins, in spite of the small calibre of the arterioles; and if the capillaries and small arteries were large, the pulse would be carried over into the veins in spite of the elasticity of the arterial walls.

FIG. 87.—THE ARM FROM IN FRONT
Showing the chief arteries. (Modified from Tiedemann)

FIG. 88.—THE THIGH AND KNEE FROM THE INSIDE
Showing arteries. (Modified from Tiedemann)

We may note here also that the pulse is not a simple throb, but consists of two parts; first, a strong, abrupt "beat," and immediately following, a second "weaker beat." These cannot be felt as separate with the naked finger, but are detected with a pulse recording apparatus. The first part of the pulse wave is caused by the sudden rush of blood into the arteries when the ventricle contracts, while the

less prominent beat is supposed to be caused by the closure of the semilunar valves of the heart.

FIG. 89.—THE LOWER LEG FROM BEHIND
Showing arteries. Many of the muscles have been removed. (Modified from Tiedemann)

### RATE OF BLOOD FLOW

With such a powerful organ as the heart driving the blood about the body, the blood current is fairly swift. The blood flows rapidly in the large arteries, but as they branch, the total area of arteries becomes greater, so that it flows more and more slowly; just as a river flows swiftly through a narrow gorge, but more slowly when it spreads out into a broad stream. In the large arteries near the heart blood flows at the rate of about sixteen inches per second. Farther from the heart the rate is about nine inches per second; in the smaller arteries it is much slower; in the capillaries it flows not more than $\frac{1}{50}$ inch per second. After passing into the veins the rate increases and as the veins merge into trunks and finally reach the heart it is about as rapid as in the arteries that leave the heart. It is in the capillaries that the blood exchanges new food materials for worn-out matter, and oxygen for carbon dioxid; and to allow this to take place to advantage a very slow flow is necessary. The length of time required for the blood to make a complete circuit of the body is calculated at twenty-eight seconds, requiring thirty-two to thirty-four heart beats.

### THE VASO-MOTOR SYSTEM

**Regulation of the Size of the Blood Vessels.**—By changing the rapidity of the heart beat, the whole body may be made to receive more or less blood than usual; but

there is another method of modifying the amount of blood received by the separate organs. If the only method of increasing the amount of blood sent to any organ were by accelerating the rate of the heart beat, thus increasing the circulation all over the body, it would be as inconvenient as if the only way of regulating the gas in a house were by turning it on or off at the gas factory. The body is therefore, supplied with a more elaborate system so that at any moment any single organ may receive a greater or less supply of blood than usual.

All the small arteries, as well as the large ones, are encircled by muscles (Fig. 82), whose contraction causes a diminution in the size of the blood vessels. If the muscles relax, the artery will become larger because of the pressure of the contained blood. The capillaries also contract and expand in a similar way. Certain parts of the brain and spinal cord are connected by nerves with all of these muscles and thus control their size. These nerves are called the **vaso-motor nerves,** and the muscles, the **vaso-motor muscles.** The muscles and nerves, together with their nerve centers in the brain and spinal cord, constitute the **vaso-motor system.**

Two sets of vaso-motor nerves are connected with the blood vessels; one of them tends to constrict the vessels, and the nerves composing it are called the **vaso-constrictor nerves.** This set is acting all the time, keeping most of the vessels slightly tightened; not sufficiently to shut off the flow of blood but enough to prevent them from becoming loose and flabby; this set supplies especially the vessels of the skin and intestine. The other set of vaso-motor nerves causes the vessels to enlarge; they are called the **vaso-dilator nerves** and are found especially supplying vessels of the muscles and glands.

**Action of the Vaso-Motor System.**—A few examples of the work of this system may make its functions clearer. We often hear people say that one should not take severe or **rapid exercise soon after eating.** Why is this so? Because,

when the muscles of the arms or legs are working they need more blood than usual. Hence the vaso-motor nerves cause the blood vessels of the muscles to relax and thus allow more blood to be supplied to them. The consequence is that less blood is at liberty to go to the cells in the stomach and intestinal walls, when these should be busily secreting digestive juices or passing along the food by peristaltic contractions. Thus, with too little blood to effect digestion the food is sluggishly handled, secretions are less in amount than they need be, and the food is not sufficiently changed to allow of ready absorption.

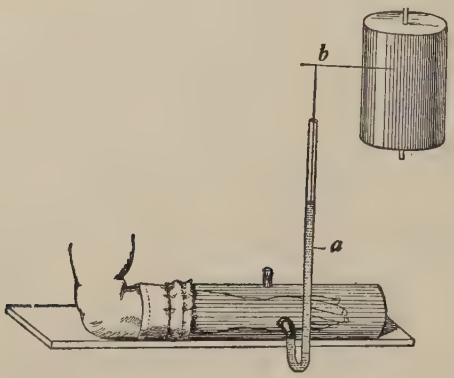



FIG. 90.—APPARATUS FOR DEMONSTRATING THE FUNCTION OF THE VASO-MOTOR SYSTEM

The arm is placed in the glass cylinder which is filled with water. The tube *a* connects with the cylinder also. Evidently any swelling of the arm will cause the level of the water in the tube to rise. Having noted, by the marker, the height of the water, the person whose arm is in the cylinder is set to studying hard. The marker quickly falls, showing that blood has left his arm to go to the aid of the hard working brain. If he stops studying the marker rises again. (Fick)

Blushing and turning pale are evidences of the work of this system. These changes are due entirely to the difference in the size of the blood vessels of the face and are brought about through the influence of nerves; Fig. 90.

**Control of the Vaso-Motor System.**—These messages to the blood vessels go out from the brain without any consciousness on our part, however; in fact we cannot control them, as is shown by the vain struggles of people to keep from blushing when they are embarrassed. This is a most fortunate pro-

vision, too; for the different organs of the body need different amounts of blood at different times, and if this blood supply were dependent on our conscious regulation of it, we could accomplish very little else, and even that function would be imperfectly performed.

The dilator influences, however, do not arise in the same place as do the constrictor; the nerves which carry messages causing constriction of blood vessels rise in the medulla, or hind brain. From there they go down the spinal cord, and are thence distributed in various directions. The **vaso-constrictor center,** therefore, is in the medulla, or hind portion of the brain. No definite place can be determined, however, as the centre from which messages go out to cause vessels to enlarge. Some fibres apparently arise in the vaso-constrictor center, while others do not.

### IMPORTANCE OF A VIGOROUS CIRCULATION

We seldom realize the fact that the whole body is traversed in every direction by arteries, veins and capillaries and that blood, a living stream under considerable pressure, is running through it every minute of our lives.

A swift brook, dashing down a steep hill, takes along with it everything but the large pebbles and stones; all the loose mud and dirt are carried along, and are left behind only when the stream becomes sluggish and slow. Then the materials in the muddy water catch on the grass and sticks in the stream, and everything under the water is covered with dirt and refuse. So when the blood flows strongly and steadily, it can pick up many of the wastes of the body and carry them away. This, however, is not due solely to the swiftness of the stream, but because, by means of this rapid flow, more blood is brought to and carried away from every spot in the body; and the more blood there is coming into contact with any tissue, the more effectually that tissue is fed and the more perfectly it is cleansed of its waste debris. In the business world there is

usually a supply of those things for which there is a demand; just so here, the "law of supply and demand" is constantly holding true; blood will flow rapidly and vigorously whenever one does things which demand a plentiful flow. Vice versa, a sluggish flow is the rule where the habits of the person are sluggish.

This is the reason for the bracing effect produced through the stimulation of the skin by rubbing, as after a bath; for this affects surface capillaries, and their walls relax. The inrush of blood reacts on all the contributing arteries, and a readjustment of many vessels takes place, rousing them from their inert condition. In the same way the skin is stimulated by fresh air, with its accompanying changes of temperature, which produce a response in the vaso-motor system creating a mild, though extensive effect on the whole body. One single pursuit, one single kind of activity, mental or physical, makes the supply and demand one-sided. Diversity of exercise and interest is necessary to secure "a sound mind in a sound body," an indispensable requisite, if one is to meet life with thrill and enthusiasm. Exercise, either in work or recreation, produces a demand for new materials, for fresh blood. Change in one's train of thought, as in congenial, lively conversation, upsets the listlessness of the nerve centers, affects the rate of blood flow, and tones up the whole system.

**The Influence of Heat and Cold upon Circulation.**—Changes in temperature cause great modification in the activities of all organs in the body. As a rule all living tissues work with greater readiness when warm than when cold. The influence of *heat* is especially noticed in its effect on the blood vessels in the skin; when the body is warm the walls of the arteries in some areas relax more than usual, the capillaries become over-full and one is said to be "flushed with heat."

On the other hand cold causes blood vessels to contract, and all the muscles to act slowly. The first effect of going

out into the cold air may be a whitening of the skin; but later an expansion of the capillaries causes the skin to become flushed. The expansion and contraction of these vessels explain our *feelings of warmth and cold.* The blood in the interior of the body is considerably warmer than that on the surface. Since the nerve endings which perceive sensations of heat are located in the skin, and not in the inside of the body, one has no sensation of heat so long as the warm blood is in the internal organs. But if the body is exceptionally warm, from vigorous exercise, for example, the blood vessels in the skin relax for the purpose of allowing the hot blood to flow more rapidly through the skin, that it may be cooled off. This extra rush of warm blood to the skin produces a sensation of heat. In other words, the feeling of warmth which one has on a warm day or after exercising, is simply a sign that the body is cooling off as rapidly as possible. On the other hand, on a cool day, the body wishes to retain its heat, and the blood vessels in the skin are consequently constricted. The skin feels cold because there is so little warm blood flowing through it. Thus the feeling of warmth does not necessarily mean that the body is hotter than usual, but only that the arterioles in the skin are relaxed and that warm blood is flowing rapidly through them. If the skin is flushed, one feels warm even though he is losing heat and so actually becoming colder.

**Fainting.**—The common and very unpleasant experience of fainting is due to a smaller supply of blood than usual in the brain. This condition may be brought about by many causes, e.g. by the lack of a sufficient amount of oxygen in the air, by the presence of a disagreeable odor, or by some disorder in the digestive functions. The last named cause is the most frequent. In such cases the action of the heart may be slower than usual or the vessels in the brain may contract so that it is insufficiently supplied with blood. This causes a stopping of its regular activities, and the person becomes un-

conscious. If he can be placed flat on his back with the head lower, if possible, than the rest of the body, blood will run into the brain again, and the person regain consciousness. While a fainting person may seem to need immediate attention and help, the common tendency for everyone who is near to rush to his relief is unfortunate. There is usually no especial danger, and if two or three are waiting on the patient others may much better remain quietly away, and thus not prevent free circulation of air, about the patient, who will doubtless very quickly recover.

**The Effect of Drugs upon the Circulation.**—The whole circulation may be more or less profoundly modified by various drugs, some of which increase and others decrease its action. Caffein, for example, the active principle in coffee causes the heart to beat more forcibly and at the same time causes a constriction of the small arteries so as to raise blood pressure. For this reason it is called a stimulant.

It has been frequently stated that alcohol increases the activity of the heart. Careful experiment, however, shows that not only is its effect not that of a stimulant, but that when used in large amounts it very markedly weakens the action of the heart. If taken in small amounts only, the heart sometimes shows a slight increase in its rate of beating, but this occurs only when the brain becomes excited, and if the person is kept quiet no change in the heart beat is noticeable. Its primary action is thus on the brain, as we shall find later.

A second effect of alcohol is more evident. The small blood vessels in the skin are enlarged, probably from the partial paralysis of the vaso-motor center. This produces a flushed skin, a feeling of warmth and a false feeling of increased circulation. Its result is to send more blood through the skin with a consequent extra loss of heat. This action is evidently not due to stimulation but to the relaxation of the muscles and is thus a decrease of activity rather than an in-

crease, even though the blood does flow a little more rapidly through the skin. These facts make it clear that alcohol cannot properly be called a stimulant of the circulatory organs.

### THE LYMPH SYSTEM

**Source of Lymph.**—Blood in its usual condition occurs only in blood vessels, and so long as it is in the vessels the innumerable living cells of the body cannot profit by the nourishment it contains. But while it is passing through the capillaries, the liquid plasma, together with some of the white

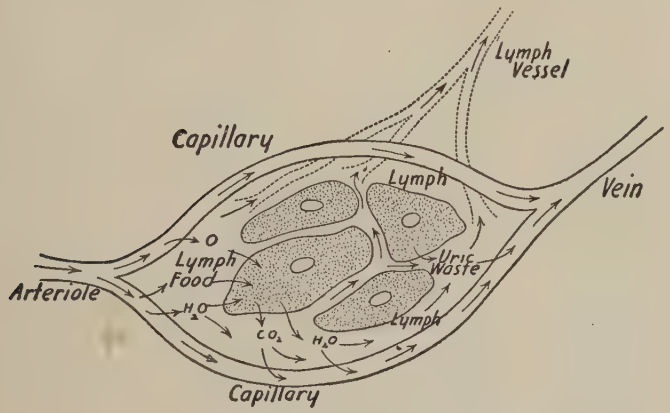



FIG. 91.—DIAGRAM

Showing the origin of the lymph and the interchange of material between the living cells and the lymph. Oxygen, various food materials, and water pass from the capillaries to the cells via the lymph. The cells give up, e. g. carbon dioxid, uric waste and water, which is carried away either through the veins or through the lymph vessels.

but with none of the red corpuscles, oozes out through the thin walls of these vessels. Outside (see arrows in Fig. 91), this plasma flows irregularly in all directions among the living parts of the body, actually bathing the cells. It is no longer known as blood but as **lymph** and soon collects in small vessels called **lymph vessels**; Fig. 92. This lymph is a clear, watery fluid, containing in solution all of the food

materials which have entered the blood, and the body cells take their nourishment from it. Moreover, the waste products which arise in the body are ejected from the cells directly into the same lymph. The lymph, therefore, serves both to supply the cells with their nourishment, and to receive their waste products. It is thus an extremely complicated solution, containing all the material which the body absorbs, and all the excretions which the body produces.

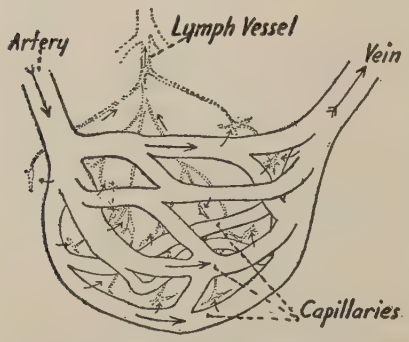



FIG. 92.—DIAGRAM
Showing the beginning of the lymph vessels and their relation to the capillaries.

**Flow of the Lymph.**—We may obtain a better idea of the flow of the lymph and of the lymphatic vessels, by making a comparison. Suppose a gravel walk extends from the top to the bottom of a hillside. At the time of a heavy rainfall all the pebbles in the walk will be bathed in the water that runs over them. Let these pebbles correspond to the cells in the extremities of the body, bathed in lymph. As we go down the hill a little distance, we notice the water running together in little shallow streams; no definite channels of any depth will be formed, perhaps, but there will be little rills in which the water runs. These correspond to the beginnings of lymph ducts not as yet definitely walled in.

As we go farther on down the hill, we find streams of considerable size made by the flowing together of the small rills. These larger streams flow in very definite channels, and there are banks on each side which keep the water in one route. These definite streams may correspond to the larger lymph ducts, with walls of their own. All along the course of these

larger streams, both on and away from its banks, the pebbles continue to be wet with the rain, and the tiny rills flow constantly to join the larger current, until, at the foot of the hill, there will be, perhaps, a single large stream carrying all the water that has fallen in the path.

In a similar way the lymph collects, at first in indefinite channels without walls, but farther on in tubes with walls, which are then called **lymph vessels.** Figure 92 shows the way in which these lymph vessels originate, and Figure 93, which shows their numbers in the superficial tissues of the arm, only exemplifies the abundance with which all parts of the body are supplied.

**What Becomes of the Lymph?**— Lymph is primarily the liquid part of the blood squeezed out of the capillaries. It must go somewhere, for if it continued to accumulate, it would form pool-like masses among the tissues. Sometimes lymph does gather in certain spaces; e.g. the trouble called **water on the knee** is caused by the accumulation of lymph in that joint as the result of an injury. Severe rubbing at any point in the skin causes lymph to collect and form a **blister.** A large gathering of lymph produces the disease called **dropsy.** Ordinarily, however, lymph flows away as fast as it appears.

FIG. 93. — THE LYMPH VESSELS IN THE SUPERFICIAL TISSUES OF THE ARM

The lymph vessels coming from all parts of the body finally unite into two large trunks. Lymph from the lower part of the body flows into the large **thoracic duct** (Figs. 65 and 94),

which, as we have already noticed, receives the lymph from the intestine and consequently the fat absorbed into the lacteals. It is also joined by subordinate vessels from the left side of the head and left arm, and then empties into the left sub-clavian vein in the shoulder region; Fig. 94. The lymph from the right arm and right side of the head flow together into a smaller vessel which empties into the right sub-clavian vein. Thus the lymph, which originally came from the blood, after flowing through the system of lymph tubes, gets back again into the blood, producing a continuous circulation of lymph from the blood to the living cells and back again to the blood. Lymph transfers the nutriment directly to the living cells and then brings back to the blood the excreted products which are then carried to certain organs for elimination.

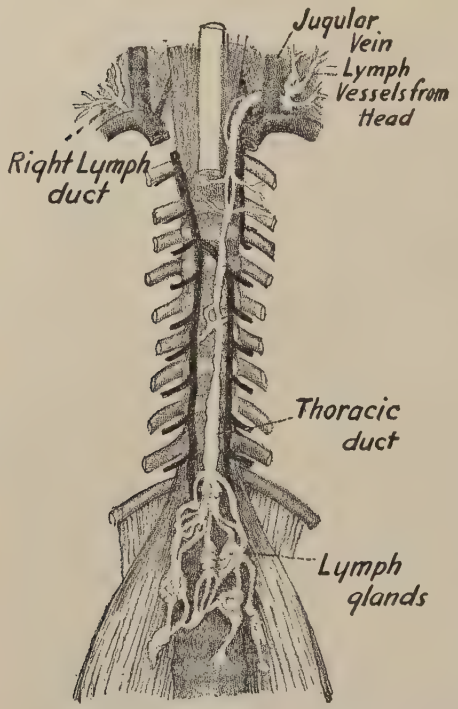



FIG. 94.—SHOWING THE COURSE OF THE THORACIC DUCT
Its entrance into the vein in the neck and also the right lymphatic duct.

## DUCTLESS GLANDS

In different parts of the body are a number of organs, some-

times called **ductless glands,** which do not seem to belong to any of the general systems. Since one type of these is associated with the lymph system, all of them will be mentioned here.

A gland (Fig. 95) is a collection of cells, the protoplasm of which takes from the blood more fluid than is used in the cell itself, and changes it chemically, after which the extra amount is secreted, or shed into some cavity, (as the pericardial cavity for example), or into some narrow passage or duct (as for instance, those of the salivary glands). There are, however, some glands in the body which do not empty their secretions into any duct or cavity; they are plentifully supplied with blood vessels, and so have much material at hand from which to make quantities of a special kind of secretion. Whatever fluid they make is poured directly into the blood vessels and the substances they furnish are called *hormones.*

FIG. 95.—DIAGRAM OF A SIMPLE GLAND
Showing the secreting cells and the blood vessels supplying them.

**Lymph Glands.**—The first of these ductless organs are the so-called **lymph glands.** These are small, more or less round masses of tissue, scattered along the course of the lymph vessels; Fig. 93. They are found in many parts of the body, particularly at such places as the shoulder and hip joints. At present practically nothing is known of their functions, although it is believed that they are the seat of white blood corpuscle formation.

**The Spleen.**—The spleen is located near the lower wall of the stomach and is supported there by folds of the mesentery; Fig. 78, page 146. So plentiful is its blood supply that when

seen in the living animal it shows distinct shrinking and enlargement in size with each beat of the heart. The size of the organ, too, would lead one to think that it must be of considerable importance. In many animals it is as long as the stomach itself, though not so broad. The use of the spleen is not known. It can be entirely removed from the body without fatal results. Various suggestions have been made as to its functions; some think it concerned with the making of new red blood corpuscles, while others take the opposite view, that it is a place where old corpuscles are destroyed.

**The Thyroid Glands.**—The thyroid glands are located, one lobe on each side of the œsophagus, a little below "Adam's apple," or the voice box of the trachea; see Fig. 98, page 178. Their influence on the living processes in the body is much more evident than that of the spleen. The material which they pour into the blood has a very definite effect upon the manner in which the blood nourishes different parts of the body. If a person is born lacking these glands, there is, apparently, a case of badly regulated nutrition; the child grows up with a stupid brain, weak limbs and a misshapen body—a condition called **cretinism.** If such a child is given a medicine containing the extract of the thyroid glands of some animal, the trouble is frequently removed, the body recovering its shape, and a normal development resulting. The enlargement and disease of the thyroid glands sometimes appears as great swellings on the neck, a trouble known as **goitre.**

**Adrenal Bodies.**—Just above each kidney is located a small gland, about the size of a walnut, called an **adrenal body.** These bodies, too, empty their secretion into the blood as it passes through them. While the amount of their secretion in a given time is small, the fluid contributed is very potent. Its main effect is to influence the muscles in the walls of the arteries so that they contract and lessen the calibre of the vessels. Under normal, healthy conditions, the

amount of this secretion is probably just enough to cause the walls of the arteries to maintain a certain amount of contraction, thus preventing them from being too lax.

**Other Ductless Glands.**— There are several other ductless glands, one connected with the thyroid called the **parathyroid**; one connected with the brain, **pituitary body.** The pancreas also, besides furnishing digestive juices to the intestines through its duct, gives other important substances to the body through the blood. The exact and entire function of these ductless glands is not fully understood.

One must not presume, however, that these glandular organs just mentioned are the only ones which pass into the blood as it goes through them substances which are essentially hormones in character. Probably it is safe to say that *every tissue in the body makes its contribution* and in this way sends material to every other tissue, definitely influencing it in one way or another.

*In health, then, each tissue gives out its own hormone in such quantity and of such quality that all other tissues are benefited by it. This fact should come to us as a suggestion that, by careful eating, breathing, sleeping, and exercise, each tissue is kept strong and healthy and so contributes to the strength and health of the whole body.*

## CHAPTER XII

## THE RESPIRATORY ORGANS

The daily distribution of food materials in a city seems a wonderful accomplishment; delivery of milk and eggs, for example, from thousands of farms to, perhaps, a million inhabitants, scattered in thousands of houses, apartments and flats is made at least every twenty-four hours. In the body, however, there are more than a million times as many cells as there are people in any city on earth; yet each cell receives its food much more often than once a day.

Besides food, another substance is delivered to the body cells by the blood; this is oxygen.

### THE FUNCTION OF RESPIRATION

No living thing, animal or plant (except a few bacteria) can subsist without it. Unicellular and many other lower organisms absorb it directly through the body surface; others (insects) are provided with branching tubes which lead air from the exterior to the internal cells; while others have special breathing organs, such as lungs or gills, from which oxygen is absorbed by the blood.

To understand why we need oxygen we have only to return to the comparison of the body to a furnace. If all the dampers in a stove are closed, the fire burns slowly, or else goes out. If all the cracks and joints in the stove could be closed air-tight, the fire would never burn. If the drafts are opened and air let in, the fire burns rapidly. It is the union of the wood or coal with oxygen which results in its "burning," and giving off heat.

Of course there is no flame in the body; the food materials inside it never glow like coals, but they do combine with oxygen and give off heat, very slowly it may be, but none the less certainly. The process is essentially the same as that

which takes place in the burning or oxidizing of fuel in a stove. If all air (oxygen) were kept from entering the blood, i.e. if the dampers were shut, the foods, even though digested and in the blood, could not be oxidized, and would be only so much dead weight and of no value. The stove is connected with a chimney to carry off the smoke and other gases that are formed in the burning fuel. Gases are also formed in the body by the oxidizing of foods, and these likewise must be passed off. The body needs to exchange gases with the air. **Respiration** is the process of gas exchange in the tissues of living things.

## THE NOSE AND PHARYNX

Figure 40 shows the structure of the nasal passages. Air enters by the two **nostrils** into the **nasal chambers,** or canals which are separated from one another by a partition made of cartilage and connective tissue in front, and strengthened farther back by a thin vertical sheet of bone. The canals pass back through the nose, just above the hard palate, and enter the upper portion of the pharynx by separate openings.

The bony and cartilaginous partition between the two nasal canals presents a fairly smooth surface; but the opposite wall of each canal has, projecting into it, a much folded, wrinkled, spongy arrangement of thin bones, the **turbinated bones**; Fig. 96.

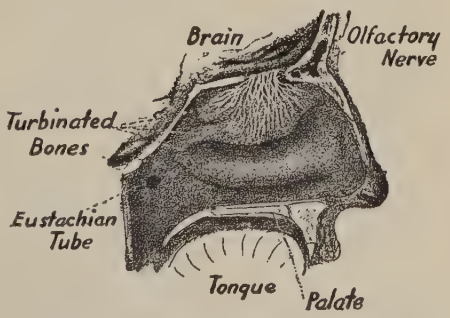



FIG. 96.—VERTICAL SECTION THROUGH THE NOSE

Showing the turbinated bones and the olfactory nerve entering from the brain into the upper nasal passages.

The walls of the nose cavities are covered with a smooth epithelium which contains innumerable **mucous gland cells.**

These keep the membranes always moist, even though the air which is constantly going back and forth through the nose would tend to dry them. In addition to the gland cells of the nasal membranes, there are, mingled with them in the deeper parts of the canals, many **ciliated cells,** whose cilia are in constant motion, causing a current in the mucous fluids. The turbinated bones might seem to be actual obstructions in the nasal passages, but they really serve a double purpose.

1. They so fill up the passages that very coarse materials taken in with the air are strained out by them, but a far more effectual cleansing is obtained because the canals running between these bones are so crooked. Particles inhaled through them lodge and stick on their moist surfaces, so that they may be driven away by the cilia, which beat about in such a way that they gradually push along any dust which touches them, until it is driven from the air passages into the throat, where it is swallowed with the saliva or expelled from the mouth. In this way the dust particles of the air are prevented, to a considerable extent, from reaching the lungs.

2. During cold weather, the position of the turbinated bones in the nose passages and the warmth of the membranes which cover them make them serve, almost precisely, the purpose of a radiator. Just as air forced over steam pipes is warmed, so air breathed through the meshes of the turbinated bones is warmed and thus does not chill the delicate lung passages.

These facts explain, in part, the injury that may result from *mouth breathing.* When the mouth is open, air rushes rapidly into the throat and lungs, carrying dust particles along with it. Moreover, such air is not properly warmed and is taken into the lungs too cold. These two things make a person more liable to diseases of the throat and lungs, and because of the close connection between the ears and the throat, sometimes produce deafness. For the benefit of his future health, every young person should notice carefully

how he breathes. The pernicious habit of breathing through the mouth is easily overcome, either by a little care, or with the aid of a surgeon; see page 177.

**Lachrymal Canals.**—Everyone has noticed that when tears are running freely, they somehow get into the nose, whence they may run out of the nostrils, but more often they pass back to the throat and are swallowed (a child is seen swallowing frequently when crying hard). Two tiny, ciliated canals leave the inner corner of each eye and carry the tears to the tear sac, which is located very near the eye in the tissues of the nose. From each tear sac a canal, about three-quarters of an inch long, passes down to open into the nose chamber of that side where the secretion is ordinarily discharged.

**The Sense of Smell.**—The sense of smell is extremely delicate. Whatever the something is which passes from an object to the cells lining the nose, it must be exceedingly minute, otherwise the object giving off the odor would entirely waste away in a very short time. Perfectly dry substances, such as balsam needles and sachet powders, give out fragrance for years and yet do not lose appreciably in weight. If a bottle of peppermint oil be opened for a few minutes, its odor will fill a house, and yet if weighed in delicate scales, no appreciable amount will be found to have disappeared from the bottle.

The upper passages in the nose, where the olfactory sense is located, are separated from the brain by a very thin partition, the **ethmoid bone.** This bone is perforated by numerous short canals, through which **olfactory nerves** pass directly from the front end of the brain. As soon as they enter the nose they subdivide into numerous fine fibres which end among the olfactory cells, both on the middle partition and on the upper and middle turbinated surfaces; Fig. 96.

The main passages through which air is drawn in ordinary breathing lie in the lower part of the nose and go nearly straight back from the nostrils to the openings into the

pharynx, or throat. The main current of air does not enter the spaces high up in the nose, between and somewhat below the level of the eyes, yet it is the lining of these upper passages that is especially constructed for smelling. The two chief kinds of cells in this lining are: **mucous cells,** which are cylindrical and rather large, and the true **olfactory cells,** which are slender and rod-like; Fig. 97.

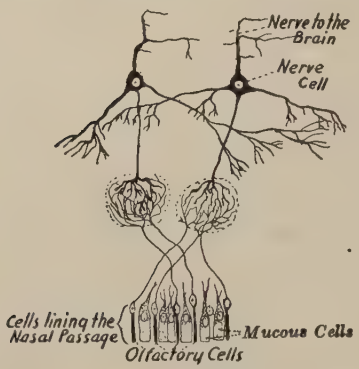



FIG. 97.—THE NERVES AND CELLS CONNECTED WITH THE SENSE OF SMELL

The olfactory and mucous cells are on the surface of the nasal passages, the rest of the cells and fibres being within the other soft tissues in the nose. (Schäfer)

Just what happens to the olfactory cells when scented air enters the nose, is not known; but in some way they are irritated and hand over to nerve fibres connected with them a message which is carried to the brain; and this message produces a sense of smell.

The olfactory area is too high in the nose for the main currents of air to pass over it. Consequently, when one wishes to perceive very faint odors, the muscles of the nose contract slightly, widening the passages, and one "sniffs" the air. By this we mean that one draws in the air in short, quick breaths, which dislodge the air already in the smelling region, and fill it with a new supply. These movements of the nose and the sniffing process are seen most plainly in animals, like dogs or foxes, which use this sense in locating food.

**Adenoid Growths.**—Adenoids are unusual growths just back of the nasal canals, in the region where these open into the pharynx. Occasionally they occur as far down as the tonsils, in which case the tonsils, too, are generally in-

flamed. They usually take the form of small bunches, varying from the size of a pea to that of an almond. Sometimes they are stalked, and have the appearance of tiny mushroom-like elevations. They occur most frequently in children between the ages of ten and fifteen years, and are, apparently, not induced by any particular exposure. They are growths of useless tissue, sometimes rather tough and wart-like, but more serious than warts, because they grow in the delicate breathing passages. Their presence may make breathing through the nose difficult and so induce mouth breathing. They may impair hearing by closing the passages into the ears and they prevent the perfect development of the whole body. They should always be removed before they become numerous. The operation is a simple one, easily performed by a skilful surgeon. If one finds his nose constantly "stopped up" so that he cannot breath through it easily, he should have it examined by a physician to see if the trouble is due to adenoids.

### THE TRACHEA

After passing through the nose and reaching the pharynx, air is drawn to the lungs through the windpipe or **trachea**, beginning with the enlarged portion, the **larynx**; Fig. 98. The trachea is about five inches long and three-fourths of an inch in diameter. It leaves the pharynx cavity just back of the tongue; the opening into it, the **glottis**, is covered by a lid called the **epiglottis**, made of connective tissue and muscle, supported on a framework of cartilage; Fig. 40. During ordinary breathing it is raised, leaving a free, open passage for the entrance of air. When food is swallowed, it closes down over the glottis, preventing particles from "going the wrong way." If, by chance, a bit of food passes by it into the windpipe, a violent spasm of coughing takes place. The trachea is held open by a number of **cartilaginous rings** in its walls, so that the air may pass freely through it; Fig. 98.

These rings are not complete but are in the form of irregular horseshoes with the open part behind, where the windpipe comes next to the œsophagus. The windpipe is, therefore, soft and flexible next to the oesphagus so that the swallowing of food through the latter is not hindered. As long as the larynx is open and the epiglottis is raised, air drawn in either through the nostrils or the mouth passes with perfect freedom down the windpipe into the lungs.

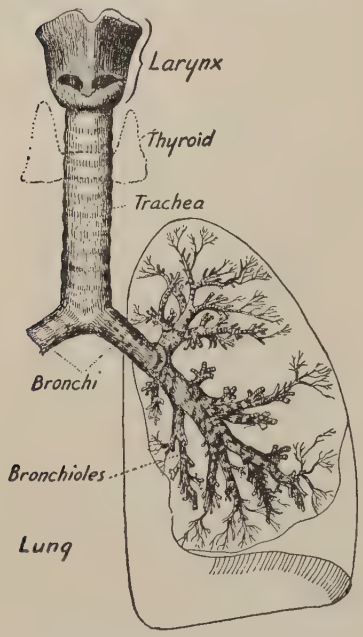



FIG. 98.—THE TRACHEA AND LUNGS
Showing the air passages. The position of the thyroid glands is shown in dotted lines. (Modified from Sappey)

### THE LUNGS

Where the lower end of the trachea enters the thorax, it divides into right and left **bronchial tubes** which immediately enter the lungs. Each lung is an elongated, elastic bag of spongy tissue and completely fills one half of the thoracic cavity, if we leave out of account the part occupied by the heart and large blood vessels. The shapes of the lungs cannot be easily described, since each fits closely about the bordering structures, the heart, the walls of the cavity and the diaphragm below. The right lung is a little larger, though shorter, than the left; Fig. 73. The lungs are divided into lobes, alike in construction; the right lung has three and the left two lobes, each lung thus being a compound structure.

**Air Passages in the Lungs.**—In the lungs each bronchial tube, or **bronchus,** divides into smaller branches, called **bronchioles,** and these divide, until finally they become minute twigs, as shown in Figure 98. At the end of every twig, the air passage is swollen into a chamber, or series of chambers, somewhat larger than the passage itself. These little air spaces are known as **alveoli,** and each is partially subdivided into smaller compartments, "air-sacs" or "air-cells." There are thousands of them in each lung, and they are the places where blood and air exchange gases. This construction provides a very large amount of surface, it being estimated that the area so provided amounts to about 960 square feet; this is *over one hundred times the skin surface of the body.* The walls of the alveoli are very thin and elastic, so that they are expanded when filled with air, and would become shrunken and nearly collapsed if emptied.

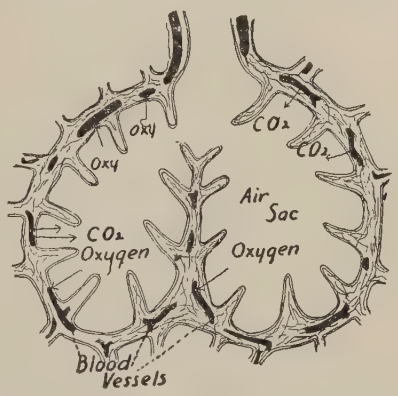



FIG. 99.—TWO OF THE AIR SACS IN THE LUNGS

Highly magnified. The black lines are sections of the capillaries that fill the walls of the air sacs. The arrows show the direction of the exchange of gas.

In spite of the filtering that the air receives in its passage through the nose, much fine dust is constantly passing into the windpipe and lungs. This would produce trouble were there no means for its removal; but the whole series of passages, the trachea and all the bronchioles in the lungs, are lined with the tiny, waving, hair-like bodies we have called **cilia;** Fig. 3 *d.* These cilia are in constant motion, creating a current upward toward the pharynx, and any dust taken in with the air and caught on the moist surfaces is carried up-

ward toward the throat, to be finally expelled from the mouth in the sputum, or to be swallowed. When working or riding where it is very dusty, although one may have cleared the throat of what mucus, saliva, or dust has collected there, after waiting for a time he finds on clearing the throat again, that more dust has accumulated. A service which can hardly be overestimated is thus performed for us by these minute ciliary projections from the cells in the air passages.

**Blood Vessels in the Lungs.**—A second set of passages in the lungs is that of the **blood vessels.** We have already noticed that the pulmonary artery from the right ventricle divides, sending a branch into each lung. Each of these branches separates in the lungs into smaller and smaller divisions. These minute vessels finally break up into extremely complex sets of capillary vessels in the walls of the alveoli; Fig. 99. The walls of these air sacs, as well as those of the blood vessels, are extremely thin and the blood, flowing in the capillaries, is brought into very close relation with the air. There is, of course, no actual contact, for the blood remains in the blood vessels and the air in the alveoli; but the membranes that separate them are extremely thin, so thin indeed, that they do not form any hindrance to gaseous exchange between the air and the blood in the alveoli. In other words, the gases in the alveoli pass with perfect readiness into the blood, and gases that are dissolved in the blood can with equal ease pass out of the vessels into the alveoli. It is while the blood is flowing through the capillaries in the walls of these alveoli that changes, which constitute an important part of the process of respiration, take place.

**The Pleura.**—On the outside of the lungs is a double fold of membrane called the pleura; Fig. 73, page 136. To understand its relations, imagine a large, thin, flexible bag, completely closed at its top and bottom, to be wrapped around the lungs. One side of the bag would thus be in contact with

the lungs and the other side with the walls of the thorax. Between the two would be the space that really is the cavity of the bag. When the lungs move, these two layers of the sac glide over each other. The layers themselves are made of glandular cells which secrete a clear, watery liquid into the space between them, keeping their surfaces moist and making it possible for the lungs to move without friction or irritation.

### DISEASES OF THE RESPIRATORY ORGANS

**Colds.**—The commonest ailment of the respiratory organs is what is called a **cold.** This is primarily an inflammation of the mucous membrane of the nose and throat. By the term **inflammation** is meant an enlargement of the capillary blood vessels, causing too abundant a supply of blood in the region in question and bringing about a variety of other undesirable effects, such as great sensitiveness, pain and, perhaps, fever. In an ordinary cold the mucous membrane is very sensitive, secretes an abundance of mucus and becomes swollen. This state of things may interfere with the free passage of air, since the nostrils may be so closed by the swollen membranes that one can breathe only through the mouth. Soaking the feet in hot water and drinking hot lemonade will sometimes prevent the development of a cold and is usually effective in the initial stages.

**Taking Cold.**—Perhaps there is no way of avoiding colds entirely, but it is possible to reduce their frequency. Oddly enough, the method which most people adopt to prevent colds frequently results in making them more, rather than less susceptible to this ailment. To understand this seeming paradox, we should find out first, what causes lead up to a cold. The actual cause of colds is not known though they are perhaps due to bacteria. It is quite certain that they are not induced simply by exposure to cold, as the name would lead one to believe, but are associated with the imperfect control

exercised by the vaso-motor system over the small blood vessels of the skin. Persons who live an out-of-door life, although frequently exposed to extremely cold weather, rarely suffer from colds. Those who regularly take cold baths, thereby giving their skin repeated stimulation, are almost immune against colds.

One is almost certain to take cold if he dresses very warmly, never goes out without heavy wraps, bundles the neck with a fur collar, or turns up the coat collar around the ears when out of doors and, when in doors, lives in very warm rooms. Such a method of caring for one's self will seldom fail to bring on colds. The vaso-motor system of the skin demands exercise just as much as the muscles of the legs or arms. If we fail to use our muscles, they lose the power of acting vigorously. So too, if we fail to give the vaso-motor muscles their exercise, they become sluggish. If we should wear less clothing, the skin would constantly be more or less under the influence of the ever-changing temperature of the air, so that the blood vessels would be kept vigorous and active. We might then frequently feel cold, but we should not "take cold."

As soon as one finds himself showing a tendency to colds, he should begin at once to invigorate the skin by proper stimuli and thus to tone up the vaso-motor system. A cold bath is the best means of doing this, and if a person when young accustoms himself to bathing every morning in cold water, he will soon find himself almost proof against colds; see page 162. Especially is it necessary that the neck should be stimulated by cold water, and not wrapped in furs, for this seems to be the part of the body where there is the greatest trouble.

Colds in themselves are of comparatively little importance, but they sometimes lead to more serious troubles. The inflammation which starts in the nose, as e.g. in a head cold, may pass into the throat, and then down the trachea into the lungs. A cold in the lungs or the chest is liable to produce

more trouble than one in the head. When serious inflammation attacks the lungs, however, we no longer call it a cold.

**Bronchitis.**—Inflammation in the bronchi or their subdivisions in the lungs is called **bronchitis.** It is really little more than a cold which has reached the smaller air passages of the respiratory organs, but it produces much trouble there; for many of the tubes are small and any inflammation or secretion fills them more easily and quickly than the same amount would the larger passages of the nose. In the case of a little child or an old person bronchitis may cause severe illness, or even death; but with those of middle age it is not much more serious than a severe cold, although it produces more discomfort and more distressing symptoms and is more lasting.

**Pneumonia.**—If the inflammation extends still farther into the lungs, it is liable to develop into a far more serious disease, called **pneumonia.** While this is a germ disease, and cannot therefore be originated by a cold, a cold often prepares the lungs for the ready implantation of the pneumonia bacteria. These bacteria are common in the mouth and throat (Fig. 100 *a*), but if the lungs are healthy, the germs may be inhaled without harm. When, however, the tiny air sacs in the lungs are inflamed by a cold, their surfaces offer a place where these pneumonia germs can get a foothold. Developing there, they may soon produce violent inflammation accompanied by high fever. Secretions accumulate in the air sacs, filling them partially or wholly, so that portions of the lungs may become practically solid and breathing sometimes be difficult. Of course, if all the air sacs were thus filled, death would at once result; but it generally happens that only certain places in the lungs are affected. After a time, if the trouble is not too severe, the liquid mass in the lungs begins to be absorbed, and eventually the lungs may clear up en-

FIG. 100.—*a*, THE BACTERIA OF PNEUMONIA *b*, THE BACTERIA OF TUBERCULOSIS

tirely and complete recovery take place. After recovery, however, the person may have a second attack, for this disease, unlike such diseases as scarlet fever and measles, does not render a person less susceptible to its return.

Pneumonia is one of the most dangerous of diseases and in some localities more people die from the effects of it than of any other common disease. There is no household remedy which is especially beneficial in a case of pneumonia, and every patient should be promptly placed in the hands of a physician. Every precaution should be taken to avoid the trouble, and the best way to prevent it is to guard against colds.

**Tuberculosis.**—There is another little germ which may seize the occasion of a cold to attack a person. It is called the *tubercle bacillus* (Fig. 100 *b*) and is one of man's most deadly foes. It may enter the body in any of several ways, but its chief method of entrance is through the mouth with food, or through the nose with the air. We sometimes hear it said that a person had a cold which developed into consumption. When we remember that consumption is caused by a definite germ and that a cold is something quite different, it is evident that a cold cannot turn into consumption any more than a worm can turn into a snake. But a cold in the lungs inflames all the air passages and these, when inflamed, are much more easily infected by bacteria than when in healthy condition. If one is in good health, the tuberculosis bacilli may frequently be inhaled without harming him. But if the walls of the air passages are weakened in any way, the germs may find a chance for growth.

This microscopic foe is far more dangerous than any of our larger enemies. After it has once entered the body, it may pass to almost any part of it and, stopping there, produce trouble. It sometimes lodges in the abdomen and produces serious and fatal diseases of the digestive organs. Sometimes it grows in the skin, producing an ugly trouble, called **lupus.**

Sometimes it is in the glands of the skin, causing them to swell and thus producing **scrofula.** It grows in the kidneys, causing **nephritis,** or in the brain, occasioning some forms of **meningitis.** It brings about joint troubles, one of which is **hip disease.** But the most common trouble, and the most serious of all, results when it attacks the lungs and brings on **consumption.** Here it produces nodules, or **tubercles** (hence the name, tuberculosis), causing the lung tissue to degenerate, sometimes to the extent of breaking through into the blood vessels, and producing bleeding in the lungs, or **hemorrhages,** as they are called. Oftentimes these diseased places heal, leaving the lungs more or less solid in the places where the germs have been working. But if the disease progresses sufficiently, the person becomes more and more poisoned by the germs, the lungs become more and more impaired in their functions, until death occurs. In most communities this disease causes more deaths than any other. In some, pneumonia causes a higher death rate.

**The War against Tuberculosis.**—For centuries mankind has known of this disease and has been helpless before it. Its cause was not known, no cure had been discovered, and nothing could be done to check its ravages. But in the last thirty years great advances have been made, and to-day we are armed with many means of fighting it. We have learned that not all persons who contract the disease die, as was formerly supposed. It has lately been shown that most persons who have reached adult life have at some time had an attack of this disease and have recovered without even knowing that they had had it. In such cases the attack probably appeared as a cold, which persisted for a time, but finally disappeared. This shows that even when the germ gets into the body, the body has strong powers of resisting and overcoming it. When the trouble is discovered at the outset, the chances for recovery are good, if the person attacked will live out of doors, where he may breathe fresh air

night and day, winter and summer. The sanatoria, where consumptives are taken, rely for their cures upon life in the fresh air and good food, and their patients are kept out of doors even in cold winter weather. No medicine has as yet been found that is of any use, despite the many advertisements with such claims.

The recent advance in the treatment of tuberculosis has been not so much in curing as in preventing the disease. We know enough to-day of the means of its distribution to stop it, if we could only induce everyone to act intelligently in the matter. The best way to fight it is to distribute information concerning it, as a wide-spread knowledge of a few important facts, which are becoming wellknown to-day, will do much towards checking tuberculosis. Chief among these facts are the following:

1. The disease is not hereditary, and parents do not hand it down to their children.

2. It is contagious; that is, one person may give it to another. The child may " catch it " from his parents, but he does not inherit it.

3. The germs may be carried in the air.

4. Dried sputum, or dried scrofulous discharges may contain the germs of tuberculosis.

5. Every one has considerable power of resisting the disease; this ability is increased by out-door life and good food; it is decreased by in-door life, sedentary habits, poor food and by the use of alcoholic drinks.

6. Cows sometimes have tuberculosis, and their milk may contain the germs.

The forces which can be marshalled against this dread foe may thus be easily deduced. Each individual should take plenty of out-door exercise, he should eat good, but not too rich food, and should let alcoholic drinks alone. He should be careful to use only such milk as comes from unquestionable sources, unless he first sterilizes or pasteurizes it. When in

the presence of a consumptive, one should avoid breathing air close to him while he is coughing and should take especial care not to contaminate one's hands or clothing with the sputum of the patient. To guard the public against the disease, there should be rigid insistence upon the carrying out of certain rules to prevent the dissemination of infectious material from the patient. The sputum should be burned. Spitting should not be allowed in public places. The rules given by the Charity Organization of New York are so valuable that they may be repeated here.

"Consumption can often be cured if its nature be recognized early and if proper means be taken for its treatment. *In a majority of cases it is not a fatal disease.*

"*Consumptives are warned against the many widely advertised cures, specifics and special methods of treatment of consumption. No cure can be expected from any kind of medicine or method, except the regularly accepted treatment, which depends upon pure air, an out-of-door life and nourishing food.*

"Consumption is a disease of the lungs, which is taken from others, and is not simply caused by colds, although a cold may make it easier to take the disease. It is caused by very minute germs, which usually enter the body with the air breathed. The matter which consumptives cough or spit up contains these germs in great numbers—frequently millions are discharged in a single day. This matter, spit upon the floor, wall or elsewhere, dries and is apt to become powdered and float in the air as dust. The dust contains the germs, and thus they enter the body with the air breathed. This dust is especially likely to be dangerous within doors. The breath of a consumptive does not contain the germs and will not produce the disease. A well person catches the disease from a consumptive only by in some way taking in the matter coughed up by the consumptive.

"It is not dangerous to live with a consumptive, if the matter coughed up by him be promptly destroyed. This matter should not be spit upon the floor, carpet, stove, wall or sidewalk, but always, if possible, in a cup kept for that purpose. The cup should contain water so that the matter will not dry, or better, carbolic acid in a five per cent water solution (six teaspoonfuls in a pint of water). This solution kills the germs. The cup should be emptied into the water closet at least twice a day, and carefully washed with boiling water.

"Great care should be taken by consumptives to prevent their hands,

face and clothing from becoming soiled with the matter coughed up. If they do become thus soiled, they should at once be washed with soap and hot water. Men with consumption should wear no beards at all, or only closely cut mustaches. When consumptives are away from home, the matter coughed up should be received in a pocket flask made for this purpose. If cloths must be used, they should be immediately burned on returning home. If handkerchiefs be used (worthless cloths, which can be at once burned, are far better), they should be boiled at least half an hour in water by themselves before being washed. When coughing or sneezing, small particles of spittle containing germs are expelled, so that consumptives should always hold a handkerchief or cloth before the mouth during these acts; otherwise, the use of cloths and handkerchiefs to receive the matter coughed up should be avoided as much as possible, because it readily dries on these, and becomes separated and scattered into the air. Hence, *when possible, the matter should be received into cups or flasks.* Paper cups are better than ordinary cups, as the former with their contents may be burned after being used. A pocket flask of glass, metal, or pasteboard is also a most convenient receptacle to spit in when away from home. Cheap and convenient forms of flasks and cups may be purchased at many drug stores. Patients too weak to use a cup should use moist rags, which should at once be burned. If cloths are used they should not be carried loose in the pocket, but in a water-proof receptacle (tobacco pouch), which should be frequently boiled. A consumptive should never swallow his expectoration.

"A consumptive should have his own bed, and if possible, his own room. The room should always have an abundance of fresh air—the window should be open day and night. The patient's soiled wash-clothes and bed linen should be handled as little as possible when dry, but should be placed in water until ready for washing.

"If the matter coughed up be rendered harmless, a consumptive may frequently not only do his usual work without giving the disease to others, but may also thus improve his own condition and increase his chances of getting well."

The simple discovery that a little parasite is the cause of this disease, has been the means of saving many thousands of lives. This seems hardly credible, for the discovery of the cause does not tell us of any cure. But it has shown us where the danger lies, and we can much better protect ourselves from a known than from an unknown danger. At all events, since Prof. Koch discovered the cause of tuberculosis,

the number of deaths has been steadily decreasing. In Massachusetts, for example, while in 1870 the number of deaths was thirty-six in ten thousand, there are about eighteen in ten thousand at the present time. Tuberculosis is largely a preventable disease, and if each person will do what he can to pass along information as to its cause and the methods of avoiding it, he will help to reduce the number of cases.

**Pleurisy.**—The ease of motion which we have noticed in the lungs is dependent upon the free moving of the layers of the pleura upon each other, and this in turn is dependent upon the presence of a watery liquid secreted by their glandular surfaces. It sometimes happens that the pleura ceases to perform its proper function, becomes inflamed, or adheres to adjacent tissues. In all such cases the movements of the lungs become difficult and, as a result, breathing is not so free and sometimes becomes distinctly painful. The trouble is called **pleurisy,** and may result from various causes, of which a common cold is one. While painful, this trouble is rarely dangerous, and usually passes off with proper treatment at the hands of a physician.

## CHAPTER XIII

## THE MECHANISM AND CHEMISTRY OF RESPIRATION

In the preceding chapter we have been following the course by which air passes from the exterior to the innermost chambers of the lungs. But the reason air enters and leaves the lungs as we breathe is not explained by merely noting the construction of these passages; for in spite of the various tissues composing them, these tubes are of themselves powerless to inhale even the smallest quantity of air. We often say "the lungs fill with air"; but we do not appreciate their entire helplessness, their lack of ability to make the least movement of their own accord. The lungs never fill of themselves; they fill because air is driven into them.

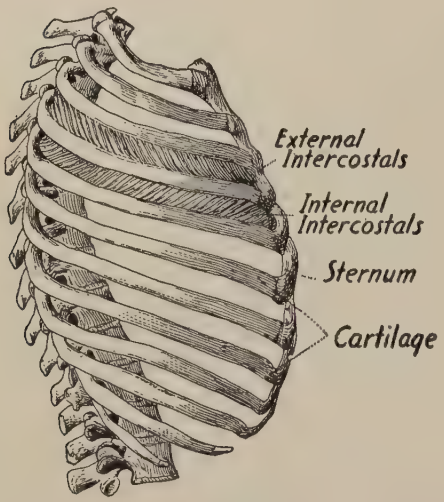



FIG. 101.—THE ATTACHMENTS OF THE RIBS TO THE BACK BONE AND STERNUM

To show their relations in breathing. Between one pair of ribs is shown the external intercostal muscles and between a second pair the internal intercostals, all other muscles being omitted.

### THE MECHANISM OF RESPIRATION

Air is drawn into the lungs just as it is into a bellows. When the space inside the bellows is increased air must rush

in through the openings left for that purpose or a vacuum is formed. The thoracic cavity is absolutely air tight; therefore, any motion which will enlarge the cavity of the chest will draw air into the lungs. The chest is so constructed that it can be enlarged in two different ways, (1) by *rib motion* and (2) by *diaphragm motion.*

**Rib Breathing.**—The ribs in the body are inclined downward and forward; Fig. 101. They are hinged to the backbone and if their outer ends are lifted, the sternum will be lifted and carried forward. This pushing forward of the outer ends of the ribs increases the distance from the backbone to the sternum, and thus enlarges the cavity of the thorax. The ribs are raised and lowered by two sets of muscles, arranged between them, called the **intercostals**; Fig. 101. When the **external intercostals** contract they lift up the ribs, pushing forward the breastbone; when the **internal intercostals** contract they pull the ribs down, thus drawing the breastbone inward. But these same motions of the ribs cause the chest cavity to enlarge and decrease in size laterally also. This increase from side to side can be understood if we imagine a pail with two handles, one hanging down on either side. If the handles are raised, each leaves the side of the pail, and the distance between their outer curvatures is greater than when hanging down. In precisely the same way, when the external intercostal muscles raise the ribs the distance between their curved sides is increased, for in their natural position they lie inclined downward along the sides of the body. When pulled back again to this position, the distance between their sides is lessened and the thoracic cavity is made smaller.

From the method of their attachment to the vertebrae the ribs can move only up and down. By looking at Fig. 123, page 253, and imagining a rib attached to the centrum and then tied by ligaments to the transverse process also, one sees that the rib can move in but the one plane like a metal hinge joint.

**It is evident then that whenever the external intercostals**

contract and lift the ribs, the chest cavity is enlarged and as a result air will be drawn in to fill the enlarged space. This forcing of the air into the lungs is called an **inspiration.** When later the ribs fall downward again the chest cavity is contracted and the air is forced out, producing an **expiration.** It is a muscular effort to raise the ribs and inspire air, but they fall back, in part at least, of their own weight.

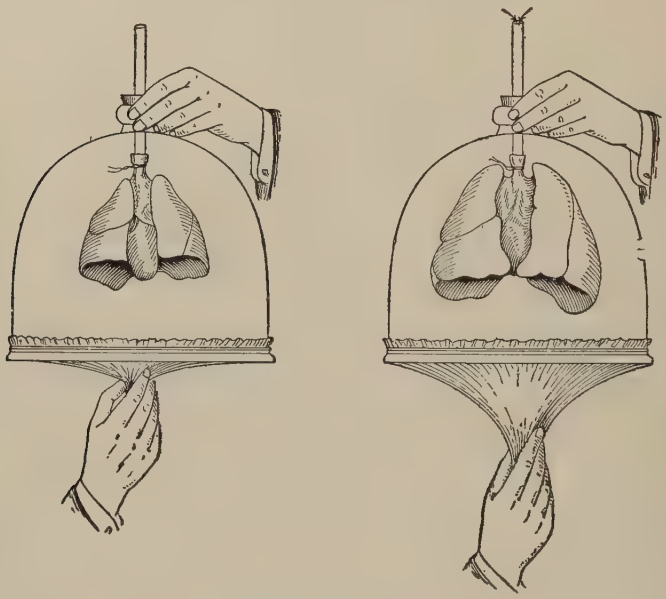


FIG. 102.—DIAGRAM

Illustrating the mechanism of diaphragm breathing. It represents the lungs of some small animal in a closed bell glass. As the rubber membrane below is pulled down enlarging the cavity, air rushes in through the tube that represents the trachea and the lungs enlarge. (Tigerstedt)

**Diaphragm Breathing.**—When at rest the diaphragm is not stretched across the bottom of the thoracic cavity in a flat plane, but arches upwards on all sides; Fig. 46, page 89. Its shape thus causes it to project into the thorax and decreases

the size of that cavity. The center of the diaphragm is a tough membrane, from the edges of which muscles radiate to the walls of the cavity. When these muscles contract, the center of the diaphragm is drawn downward and the whole structure takes a more nearly flat position. In doing this the diaphragm presses upon the stomach and other abdominal organs, forcing them downward and outward. Thus the chest cavity is increased (Fig. 102), and air is sucked into the lungs, which swell and fill the enlarged space.

At each expiration the muscles of the diaphragm relax, and the muscles of the abdomen which were stretched somewhat when the organs in it were pressed downward, now shorten, and the diaphragm is thus carried up into its former dome-like shape; the room in the thoracic cavity is consequently lessened, and air is forced out of the lungs. Breathing may thus be accompanied by a rise and fall of the abdominal walls, but this does not mean, of course, that air is taken into that cavity; merely that the contained organs are displaced at the descent of the diaphragm, and that the abdominal muscles force them back again when the diaphragm relaxes.

The reason that air rushes into the lungs when the thoracic cavity is enlarged is that air is constantly exerting a pressure upon our bodies equivalent to fifteen pounds to the square inch. As soon as the thoracic cavity is enlarged, air naturally enters it, since otherwise there would be a vacuum.

### EXTERNAL AND INTERNAL RESPIRATION

The alternate inflow and outflow of air through the passages is the most superficial part of the breathing process. All the air in these passages is still connected from the outside world, and is not yet a part of the body in any sense whatever. This tidal flow inward and outward is called **external respiration**.

Through the thin walls of the air sacs of the lungs the oxygen of the air passes, following the law of osmosis of gases, and combines with the haemoglobin of the red blood corpuscles, as de-

scribed on page 124. From the lung region the blood hurries to the innumerable cells of the body each of which is needing its share of food and oxygen. From the capillaries these pass into the lymph which surrounds the cells, and thence through the cell walls into the protoplasm. This final step is the most important of the entire respiratory process, and is naturally called **internal,** or **tissue respiration.**

Up to this point the respiratory process has been described as though serving only to carry oxygen to the cells; but this is only half the story, for in the cell protoplasm numerous elements combine with oxygen, and among other things carbon dioxid is thus formed. This passes out of the cells, into the lymph, thence into the plasma of the blood (not into the haemoglobin save in very limited degree) and is carried to the lungs; here it dialyzes through into the air sacs, and then is expelled during expiration.

## NERVOUS CONTROL OF RESPIRATORY MOVEMENTS

That breathing is under the guidance of the nervous system is evident. One can breathe fast or slowly at will; one breathes faster when he is running than when he is still, and faster when he is excited than when he is calm. These changes in the rate of breathing generally take place without any thought whatever; but they are, nevertheless, brought about under the direction of the brain. Unlike the heart, the breathing muscles are not automatic, and unless stimuli come to them from the central nervous system they will not act. The source of these stimuli is in the lower part of the brain, in the medulla, at the place known as the **respiratory center.**

No nerves go directly from the respiratory center to the intercostal muscles or diaphragm; they first go down in the spinal cord for some distance and then pass out in nerves which leave between the vertebræ. One set of nerve fibres on each side of the body leaves the spinal cord in the neck

region (Fig 103); each set passes out of the cord by three roots, i.e. by nerves between the second and third, third and fourth, fourth and fifth vertebræ. These roots unite to form a single nerve on each side which passes down through the thorax behind the lungs and then spreads out in the muscles of the diaphragm. Messages go over these **phrenic nerves** from the respiratory center to the diaphragm, but none go in the opposite direction; Fig. 103. The second set of fibres from the respiratory center, the **intercostal nerves,** go farther down the cord to the region of the ribs to emerge between the vertebræ and pass at once into the intercostal muscles; Fig. 103.

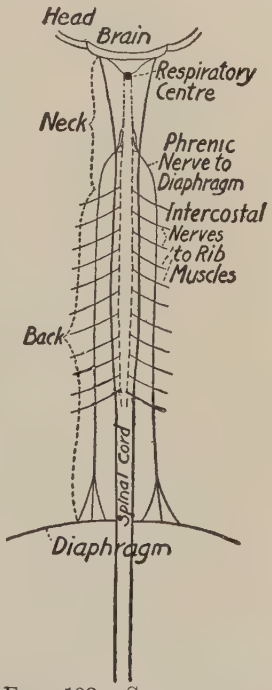



FIG. 103.—SHOWING THE ORIGIN OF THE NERVES CONTROLLING BREATHING

If these nerves which carry these impulses from the respiratory center to the various muscles concerned in breathing are cut, or if that center itself is destroyed, breathing stops at once and death follows. As long as the respiratory center is active, it sends out stimuli to the breathing muscles with perfect regularity. The action of this center is partly involuntary, i. e. goes on without any action of the will, as is shown by the fact that breathing continues while one is asleep. At the same time, that the center is partly voluntary is demonstrated by the fact that one can at any time breathe fast or slowly as he wishes. During normal life the average rate at which respiratory impulses are sent to the muscles concerned is fifteen to

twenty per minute. In case of sickness, especially in fevers, this rate may be much more rapid.

Thus, although the stimuli for breathing all come from the same general center, they go to the muscles by different courses. Since all breathing impulses start from the brain it is evident that if the neck be broken so as to cut off all connection of these muscles with the brain, breathing will stop at once. If, however, the neck should be broken below the place where the phrenic nerves leave the cord, the diaphragm would still be connected with the respiratory center and might still be capable of making respiratory movements. Under such circumstances persons have lived for years, although the lower part of the body was cut off from the brain and of course paralyzed.

The intercostal and phrenic nerves carry messages away from the brain; probably never toward it.

One pair of nerves, however, carries messages from the lungs to the brain; these are the **respiratory branches of the vagus nerves**; Fig. 77, p. 144. The messages which go over these respiratory branches are not for arousing movements, but for informing the respiratory center of conditions in the lungs, thus affecting the messages going to the muscles of the diaphragm and ribs which are then modified to meet the circumstances.

The rate and nature of breathing are not only affected by direct messages from the lungs, but by stimuli from the nose lining. Fumes from ammonia or sulfur will practically stop breathing processes for a short time. Moreover, sudden pain in the abdomen may be followed by a cessation of breathing. Dashes of cold water will set up more rapid breathing at first, though later it may be followed by a slower respiration. None of these influences on the body surface affects the breathing muscles directly; sensations go from the surface to the brain and then act indirectly through the respiratory center.

### THE CAPACITY OF THE LUNGS

With each inspiration, a certain amount of air is drawn into the lungs and with each expiration it is forced out. The lungs, however, are never completely emptied in expiration and never filled in an ordinary inspiration. At each inspiration, the average person takes into his lungs about 30 cubic inches of new air. This is called the **tidal air.** With some effort, about 100 cubic inches of **complemental air** can be inhaled and exhaled in addition to the tidal air. After an expiration of the tidal air, one can, by effort, expel an additional 100 cubic inches of so-called **supplemental air.** Even after the greatest effort of expiration there remain in the lungs about 60 cubic inches of residual air which cannot be expelled; Fig. 104. These figures are only the average, and different individuals have very different breathing habits, *i.e.* some, even in quiet breathing, inspire three times as much air as others.

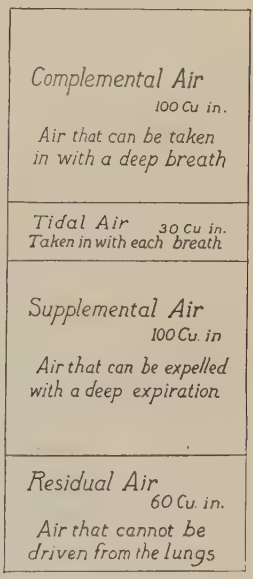

Complemental Air
100 Cu in.
Air that can be taken in with a deep breath
Tidal Air 30 Cu in.
Taken in with each breath
Supplemental Air
100 Cu. in
Air that can be expelled with a deep expiration
Residual Air
60 Cu. in.
Air that cannot be driven from the lungs

FIG. 104.—DIAGRAM
Showing relative amount of air in lungs under different circumstances.

Thus with an ordinary breath only about 30 cubic inches of the 190 cubic inches of air in the lungs of the normal individual is changed. The larger bronchi can hold 10 cubic inches of air without much difficulty and, therefore, much of the air breathed in and out is merely used in ventilating these tubes. Hence the air in the deepest parts of the lungs—that in the alveoli, or air sacs—is not wholly changed. The lungs, therefore, are never entirely filled with fresh air. The only way that fresh air usually gets into the air sacs, where it

comes in contact with the blood, is by gradual passage, or by *diffusion,* from the larger air tubes into the smaller sacs.

## BREATHING HABITS

Certain practical lessons as to methods of breathing may be drawn from these facts. Diaphragm breathing fills the lungs at their lowest point, rib breathing tends to fill the upper lobes. Either of these types alone will produce only a partial action of the lungs, and if one accustoms himself to only one type of breathing, parts of his lungs are liable to become sluggish. This inactive condition produces a tendency to lung diseases, e.g. consumption, which generally starts in the least used lobes of the lungs. Breathing should, therefore, involve the whole lung equally; neither rib nor diaphragm breathing should predominate. Among people who are not hampered by ill devised clothing, both ribs and diaphragm act freely in natural breathing. Our methods of dress interfere with this freedom. Corsets, tight bands around the waist, and the custom of supporting the skirts from the hips, interfere with women's abdominal breathing. Men have a tendency to make the breathing too exclusively abdominal. They should give particular attention to developing rib, or chest breathing, while women should especially try to strengthen their abdominal breathing. This can easily be done if a little attention be given to the matter each day. Unnecessary or needlessly tight bands about the waist are used only by those who see beauty in a weakened, misshapen form, and who hold health a cheap possession.

In an active, out-of-door life, like that led by children, soldiers or mountaineers, vigorous exercise causes very rapid breathing and thus keeps the lungs active. But the quiet life of adults in cities does not involve much exercise, and the lungs are rarely filled with fresh air. For this reason it is a very good practice for city-dwellers to take several long

breaths several times a day, filling and emptying the lungs as completely as possible.

## CAUSE OF RESPIRATORY MOVEMENTS

**The Cause of Respiratory Movements.**—None of these facts, however, tell us much about the real purpose of respiration or the actual cause of the respiratory movements; they only describe how the movements are produced and regulated.

The respiratory movements are started in the respiratory center which sends regular, rhythmical messages down the cord to the breathing muscles. What excites this center into such regular activity? In answer to this question an interesting experiment may be described. By a complicated method it is possible to send through the brain, and thus through the respiratory center, blood different from that which goes to the rest of the body. If blood containing only a small amount of oxygen is sent through it, the center begins to send out messages very rapidly to the breathing muscles, even though the rest of the body is receiving very pure blood. On the other hand, if the blood sent through the respiratory center contains an unusually large proportion of oxygen, the breathing messages are sent out more slowly than usual. If blood with an extremely large amount of oxygen be used, breathing messages become very slow no matter what kind of blood the rest of the body receives.

The logical conclusion is that the center in the brain, which controls breathing, is influenced by the condition of the blood which flows through it. When the body is doing more work than usual, more oxygen is needed, and more carbon dioxid is being formed. The blood rapidly loses the oxygen and absorbs carbon dioxid; this impure blood affects the nerve cells of the medulla, causing more rapid breathing. It is the condition of the blood in the respiratory center that ordinarily determines the rate of respiratory movements.

## THE CHEMISTRY OF RESPIRATION

Respiration is a process of the absorption and elimination of gases which occurs in all animals. Not all animals, however, have lungs. Fishes have gills for this purpose; some animals (earthworms) can take sufficient amounts of these gases through the skin and need no lungs, gills or any special respiratory organs. Yet these same animals, if not allowed to get rid of carbon dioxid and take in oxygen, shortly die. To understand respiration we must, therefore, study the relation of these gases to the blood.

**Changes in the Air During Breathing.**—1. Inhaled air contains about twenty per cent of **oxygen,** while exhaled air contains only sixteen per cent, showing that oxygen is extracted from the air while passing through the lungs.

2. Inhaled air contains no **carbon dioxid,** or only slight traces of it, while exhaled air contains four per cent. Carbon dioxid is, therefore, added to the air during respiration.

3. Inhaled air has a **temperature** which varies with the conditions. On a cold winter day, it may be below zero; on a hot summer day, it may be as high as one hundred degrees; ordinarily it will be in the vicinity of seventy degrees, the temperature at which our rooms are usually kept. Exhaled air is found to be very nearly ninety-eight degrees, the body temperature. Although there is some variation in the temperature of exhaled air, it is never much below this point. If the air is inhaled at 70° F., it will evidently be warmed in its passage through the lungs, and the body become cooled in consequence.

4. The amount of **moisture** in the inhaled air is variable. On a dry day it is very slight, while on a wet day it is very great; but exhaled air always contains nearly as much moisture as it can hold. This can easily be seen by breathing upon a piece of cold glass. The exhaled air, when cooled by the glass, cannot hold as much moisture as when it was warm,

and moisture is deposited on the glass in the form of small drops of water. This saturation of exhaled air shows that it has extracted water from the body.

The lining of the lungs is the tissue through which these exchanges are made; it is a membrane, moist because covered with unicellular mucous glands, and thus always flexible and not dried by the ever-changing air. Because of the nature of its structure, gases diffuse through it even more readily than they would go through a pure water film of the same thickness. In the instance of carbon dioxid, diffusion is three times as fast through lung tissue, as through a water membrane of equal thickness. The actual thickness of the wall of a lung alveolus is about 1-6250 of an inch (0.004 mm.)

**Changes in the Blood.**—The changes in the blood are, of course, just the reverse of those in the air. What the air absorbs, the blood has given up, and what the air has lost, the blood has absorbed. From these simple facts we learn that the blood takes oxygen from the air, but gives up to the air carbon dioxid, heat and moisture.

**How Oxygen Gets into the Blood.**—When the blood flows through the small capillaries in the walls of the alveoli of the lungs (Fig. 99), it comes very close to the air, so close that gases readily pass from the air to the blood. The air contains oxygen in large amounts and under considerable pressure; as a result some of it is at once absorbed by the liquid plasma of the blood. There is nothing unusual in this fact, for water or any other liquid will absorb gases from the air. Oxygen is forced into water by the pressure of air (15 lbs. to the sq. in.) on its surface. If water is placed in a closed chamber from which all the air is then removed, this is very evident, for the air dissolved in the liquid will come away from it in bubbles. Contrariwise, if the pressure of air or other gases above the water surface is increased, the gases are absorbed in just the degree that the pressure is increased. So too, carbonic acid gas is forced into water, to form soda or Seltzer water, and

the bubbles of gas can be seen coming out of such water when the pressure is released.

The amount of oxygen which the blood absorbs in this way is very small; by far the larger part is not simply absorbed but chemically combined with the red coloring matter, or **hæmoglobin.**

**Hæmoglobin.**—We have already seen that the blood contains red corpuscles, which are like little sponges holding in solution a material called hæmoglobin; page 124. This substance has an affinity for oxygen, and provided the gas is under slight pressure, will absorb it in large amounts whenever in contact with it. After hæmoglobin has absorbed oxygen, it is a bright crimson; but if then put in a place where there is no oxygen, or where the oxygen pressure is very slight, it will release the oxygen it has absorbed and its color will change to a bluish red. Hence arterial blood, which has just taken on oxygen in the lungs, is bright crimson, while venous blood, which contains less oxygen, is bluish red in color.

Oxygen can be absorbed by haemoglobin because of the iron element in it; by analysis it is found that a little over 0.3% is iron; one molecule of oxygen will combine chemically with every atom of iron. The oxygen capacity of the blood is thus limited; but as each corpuscle hurries through the lung capillaries, it seizes what it can absorb and hastens away to some part of the body where the oxygen is needed. There is about nineteen per cent of oxygen in arterial blood, most of it being in the red corpuscles.

**How the Blood Gives up its Oxygen.**—Let us follow the blood and see what becomes of its oxygen. After going back to the heart, from the lungs, and flowing out through the arteries, it finally comes to the capillaries in the muscles, glands, etc., somewhere in the body; for example, in the fingers; Fig. 91. Although it spends only about one second in the capillaries it loses in that short time 35% of its oxygen. This is because

no free oxygen is present in the tissues, since, as we shall see later, the muscles are using up oxygen as fast as they can get it. Here then, among the tissues where the oxygen is nearly absent, or under very slight pressure, the corpuscles give up the oxygen they are carrying and turn to a bluish red color as they flow out from the capillaries into the veins and back to the heart.

**Nitrogen in Respiration.**—Nitrogen composes about four-fifths of the air we breathe, but so far as the respiratory processes are concerned, it simply dilutes the oxygen of the air. Some of it is doubtless absorbed by the blood plasma but none of it is used in the body and practically none of it is given off from the body in the form of gas. Hence the blood comes back to the lungs from the tissues with just as much nitrogen as it had originally.

**Breathing Pure Oxygen.**—The statement that nitrogen dilutes the air is, however, open to a misapprehension. If oxygen is as active a gas as we believe it to be, what will be the effect if, instead of breathing an atmosphere which contains only one-fifth oxygen, we breathe pure oxygen? We might at first imagine that we should absorb much more oxygen. Conversely, we might suppose that, if there were less than the usual amount of oxygen in the air, we could not obtain enough. We often think that the reason air in a room becomes unpleasant and depressing is that it contains so little oxygen. All of these impressions are mistakes. Since the hæmoglobin can absorb a certain quantity of oxygen and no more, it can obtain this amount perfectly well from ordinary air, or indeed from air containing less oxygen than usual. If, therefore, one should breathe pure oxygen, the blood would take on practically no more than it does from ordinary air (a slightly greater amount might be taken in by the blood plasma, for that combination is a mere mixture). So far as the oxygen goes, there is probably enough in any air we breathe to furnish the blood properly for effective working.

**Breathing Carbon Monoxid.**—Carbon monoxid (CO) occurs in all coal gas and all illuminating gas, sometimes escaping from stoves which are badly constructed or have faulty drafts. It is carbon monoxid which burns with the blue flame often seen flickering over the surface of coal in a stove or over burning charcoal. Hæmoglobin will combine more readily with carbon monoxid than with oxygen, so that if the two are in the same air, carbon monoxid will unite with the hæmoglobin of the blood and oxygen will be excluded. If this happens, the person concerned will die of suffocation just as truly as if he had stopped breathing.

It is easy to see why leaking gas pipes and stoves are unhealthful. Gas pipes which enter sleeping rooms should be watched with especial care, for from a very slight leak enough escaping gas may accumulate during a night to suffocate a sleeping person. There is danger, too, in leaving illuminating gas turned low, for the flame may go out, blown by a gust of wind, or because the pressure is temporarily lowered at the central plant, and the room be filled with gas.

**Carbon Dioxid in Respiration.**—In oxidation some of the food products unite with oxygen and as a result another gas, **carbon dioxid,** is formed. When, for example, a candle is lighted, the tallow in it combines with oxygen, thus producing carbon dioxid. If the tallow were eaten it would, in a similar way, be united with oxygen in the body and the same gas would result. Since this carbon dioxid is a waste product, it must be removed from the body in some way and the second phase of the respiratory process is concerned with this elimination.

Whenever any of the tissues of the body are active, some food or tissue is combined with oxygen and a certain amount of carbon dioxid is formed. The blood, as it flows through the capillaries of these tissues, absorbs this gas very much as it does oxygen in the lungs, and for the same reasons; i.e. because the carbon dioxid pressure is high. By the time

the blood has gone through the capillaries it has become loaded with this gas. About 40% of what the blood carries is in loose combination with the proteid materials in the corpuscles, but this does not at all effect the freedom with which oxygen combines with the iron of the haemoglobin. About 60% of the carbon dioxid is carried in the plasma; a small part of this (about 2%) is simply dissolved in the plasma, while the rest of it is temporarily combined with other elements in the blood stream.

When the blood comes to the air sacs in the lungs it finds conditions opposite to those among the tissues; the amount of carbon dioxid in the inhaled air is very small, and the pressure is so low that the blood immediately lets go its hold on its $CO_2$, which thus passes at once into the air sacs. Thus carbon dioxid gas is breathed out at every expiration, while new air is breathed in. If this inhaled air should contain too much $CO_2$, the blood could not rid itself of its own quota of the gas, and the person would soon die.

It has been found that air containing 8-9% of carbon dioxid produces severe discomfort.

This gas, which is heavier than ordinary air, is sometimes found in abundance in deep wells or mines where it accumulates, making the air distinctly poisonous. Men who must descend into such wells frequently first lower a lighted candle. If it will burn, the air is safe to breathe; if not, no person can safely enter.

## BREATHING AND EXERCISE

Since without a supply of oxygen one cannot live, and since one would soon be poisoned by carbon dioxid if he could not dispose of it, the necessity of breathing is evident. We can easily see, too, why breathing will increase in rapidity if one exercises the muscles vigorously, as, for instance, in running. Breathing must be accelerated so as to keep up a larger supply

of air in the lungs, because (1) the blood needs more oxygen for carrying on its extra activity during the running, and (2) it is necessary to dispose of the extra carbon dioxid given off by the muscles when they are contracting rapidly. But increased breathing alone will not accomplish this end. A more rapid circulation of the blood is needed to bring the carbon dioxid to the lungs, so the heart begins to beat more quickly and the blood to flow more swiftly. As soon as the blood circulates more rapidly, however, and the gases are carried off sufficiently, the necessity for quick breathing is in part reduced. Every runner knows that after running a few minutes, he gets what is called his " second wind". Breathing grows less rapid and he may keep on running for a considerable time without any trouble with respiration. This "second wind" appears when the circulation of the blood has become rapid enough to carry off properly the gases formed.

**Evils of Indoor Life.**—Nature, apparently, intended that man should live out of doors. But we have adopted new habits of life, and shut ourselves up for many hours of the day in close rooms. Hence, we are forced to breathe air which has, perhaps, been breathed by other people and thus rendered unwholesome.

In spite of its advantages living indoors is unnatural, and is conducive to certain diseases. People who live out of doors are rarely attacked by lung diseases; while they do not entirely escape them, they are affected much less often than house-dwellers. Other diseases are rendered especially serious because we live in more or less limited spaces. But since we cannot, in the present state of civilization, pass all our time out of doors, we should do our utmost to remedy these conditions by furnishing our rooms with a proper supply of good fresh air.

**Ventilation.**—More attention is paid to the proper ventilation of buildings to-day than ever before. In the times when rougher materials were used in their construction and when

open fireplaces were the rule, so many chances were left for air to enter houses that special ventilating apparatus was almost unnecessary. With more skilled workmanship, with machine-made building materials and especially with improved methods of heating, a necessity has arisen for fresh air radiators, fans, transoms and the various ventilating devices.

The need for ventilating a room depends on the rate at which the air is breathed by its occupants. The normal person breathes from fifteen to twenty times a minute. When quiet the muscles oxidize materials slowly and the breathing rate is lowered, but any hurry or excitement causes an immediate increase in the breathing rate. Since we know that with each breath about thirty cubic inches of air is taken into the lungs, it would be easy to calculate the amount of air breathed in any given time, but this would not really tell us how much air is needed. To know this it would be necessary to find out to what degree air can be impure before it is not properly respirable. Fresh air keeps one active and alert but the air of a close room makes one feel stupid and sleepy, and even produces headache. This is not, as sometimes supposed, because there is not enough oxygen in the air, for all rooms contain sufficient oxygen to furnish the hæmoglobin with all it can hold; nor is the reason to be found in the presence of an unusually large amount of carbon dioxid. There may be about three per cent of pure carbon dioxid in the air without interfering in any degree with its wholesomeness. So long as there is not enough to interfere with the elimination of this gas from the lungs, it will do no injury, and the air of no ordinary room, however poorly ventilated, contains enough to do this. The ill effects of breathing air already breathed by other persons are partly due to the large amount of water it contains and partly to its high temperature. Perhaps other factors are concerned, but the trouble is generally neither lack of oxygen nor the presence of too much carbon dioxid.

It is therefore evident that it is no simple matter to tell just

how much air a person needs. Taking everything into consideration, those who have made a special study of ventilation tell us that each person should be allowed from 2000 to 3000 cubic feet of fresh air per hour. This amount would be contained in a room ten feet high, twenty feet long, and ten feet wide. Fortunately, doors and windows are always loose enough to allow a free passage of air through the cracks around them, for if churches, schoolrooms, theatres, etc., were built with air-tight joints around windows and doors, they would have to be made enormously large to meet the demands of the crowds which gather in them.

In arranging for the ventilation of rooms, it is well to learn and remember a few general principles:

1. A room may be well ventilated, but feel uncomfortable because it is too hot. The temperature should never be above 70°F, unless the room is occupied by very aged people. Public halls and sleeping cars, for example, are often kept so hot that they are very uncomfortable, even though there may be good ventilation. On the other hand, the temperature may be right, but the air may be poor. Too high a temperature with good ventilation is, however, the more common fault.

2. For proper ventilation, a *constant motion* of air is needed, not simply around the room, but from the room to the outside. If proper means for the escape of air is provided, plenty of air will come in around doors and cracks, to take the place of that going out. An *open fire place* is one of the best methods of ventilation. A fire in a *stove* will serve the same purpose, for it is constantly sending heated gases up the chimney, thus drawing fresh air into the room. The belief that stoves are unhealthful, because they use up the oxygen of a room, is a great mistake. They use oxygen, but they are constantly drawing in fresh air to replace it. On the other hand, *gas stoves* or *gas burners* in a room will use up oxygen; for generally they are not connected with any chimney or proper outlet, and therefore fill the air with the odor of burned

gas which is in itself undesirable. Such methods of warming a room are hygienically bad. When heated air is sent into a room from a furnace in the cellar it will produce good ventilation provided there is some ready outlet for the air of the room. Heating a room by a radiator, either hot water or steam, simply warms the air already present and furnishes no proper outlet for the stale air, often making the use of special ventilators a necessity.

3. The greater the difference in temperature between the air in a room and that outside, the easier it is to produce currents of air. In cold weather air comes in and goes out through cracks around doors and windows much more rapidly than it does in warm weather.

4. The rooms of an ordinary house are so large in proportion to the few people living in them that no attention need be given to ventilation except perhaps in very cold weather when they are more closely shut.

5. Sleeping rooms should be more carefully ventilated than living rooms. But most care is needed in schoolrooms and similar places, where many people are gathered together.

6. Expired air is warmer than the ordinary air of a room, and rises at first. As it cools, however, it sinks, because it is heavier than the rest of the air on account of the presence of carbon dioxid. Hence, while ventilators at the top of a room will take away the warmed air, there should also be ventilators low down to carry off the heavier gases after they have cooled and sunk to the floor.

**Treatment in Cases of Suffocation.**—There are many kinds of accidents that result in the exclusion of air from the lungs, or asphyxia as it is called, producing suffocation. In all cases the first thing to be done is to remove the cause of the trouble. If it be choking from compression at the throat, free the throat from whatever constricts it; if it be breathing poisonous gases, remove the patient to fresh air; if it be water, as in the most common cases of drowning, lift the patient by

the middle of his body and allow the water to run out of his mouth.

Lay the patient on his stomach with the head turned to one side so that his mouth and nose are away from the ground. Either kneel at his side or sit on his hips and then place the hands upon the small of his back, with the thumbs near the spine and the fingers spread out over the lower ribs. Then throw your weight onto the hands for about the time it takes to count three slowly, and then slowly swing yourself backwards so as to release the pressure. After three more counts repeat the whole movement. The pressure when your weight is thrown forward forces air out of the patient's lungs and the release of the pressure causes them to fill again. This produces what is called *artificial breathing*. Continue this process about twelve times a minute without any pauses. Do not be discouraged for an hour at least. Pause occasionally to see if natural respiration has started, by holding some light object in front of the nostrils. If there is any motion showing natural breathing, cease the artificial respiration and wrap the patient warmly.[1]

## THE VOICE

While the tongue is popularly associated with the voice, it is really only an agent which modifies sounds made near the entrance to the windpipe. It would be possible for one to make himself perfectly understood, even if his tongue were removed. The words spoken by such an individual would be badly pronounced, but just as loudly and nearly as intelligibly as those spoken by a normal person.

**The Larynx.** —The voice box, or **larynx,** as it is technically called, is located just below the glottis in the trachea; Fig. 98. The whole trachea is supported by incomplete rings of cartilage, but in the larynx region they are especially formed to

[1] If practical, demonstrate this process of artificial respiration upon some person in the presence of the class.

make the framework of the organ of voice. Their arrangement there is as follows:

The uppermost cartilage, the **thyroid,** a broad U-shaped cartilage, lies horizontally with the opening at the back; its front curve protrudes and is felt through the skin as "Adam's apple"; Fig. 105. The tips of the sides of the U at the back have short vertical growths on them, one extending upward and one downward on each arm of the U.

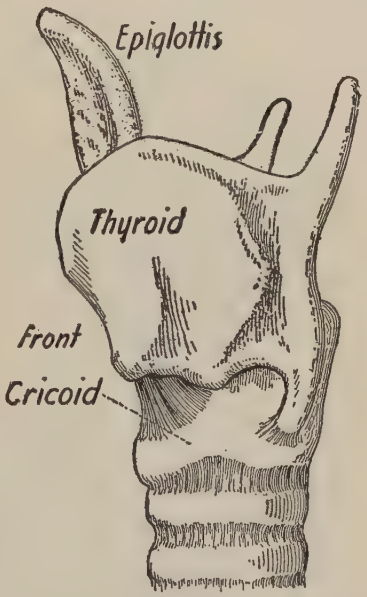



FIG. 105.—THE LARYNX AS VIEWED FROM THE LEFT SIDE
Slightly enlarged.

Below the thyroid is the **cricoid** cartilage. This is a complete ring, narrow in front and broad behind. Its lower hind border is hinged on each side to the lower prongs on the thyroid; Fig. 105. On the upper edge of the hind border of the cricoid are located the two small, triangular **arytenoid** cartilages shown in Figure 106, which represents a view looking into the larynx from above. These four cartilages together with tendons, muscles and connective tissue make up the **voice box.**

The passage through this structure will be seen in Figures 106 and 107, to be nearly closed by two transverse, curtain-like membranes attached at the back (one to each arytenoid cartilage), along the sides, and at the front (to the thyroid). In front these two membranes come nearly together, while they are separated at the back, thus leaving an approximately

triangular opening for air to go through in ordinary breathing. The straight inner borders of these membranes next to the triangular passages form the **vocal cords.**

**Sound and Voice.**—In making a sound the vocal cords are drawn very near one another at their posterior ends, and are stretched tightly; air is then forced through the slit between them. In this stretching of the cords several muscles are concerned. In Figure 106 the muscles marked *A* and *B* open and close the space between the vocal cords by moving the arytenoid cartilages to which they are attached. The muscle marked *C* will evidently loosen the cords. One of the muscles that tightens them is shown in the figure at *D*.

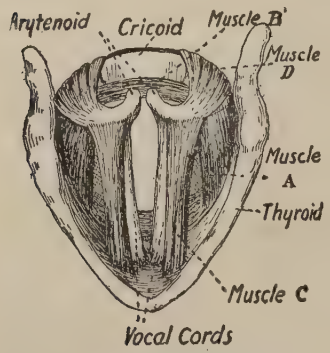



FIG. 106.—THE LARYNX AS VIEWED FROM ABOVE

A part of the membranes and muscles are removed so as to show the chief muscles concerned in opening and closing (Muscles *A* and *B*) as well as those that loosen (Muscle *C*) the vocal cords. Muscle *D* is one of those which tighten the cords. (Carter)

Essentially this same mechanism for voice production is present in many lower animals, e.g. frogs and toads, dogs, sheep, seals, etc. The song of birds is produced by a somewhat different structure.

Since sound is due to extremely rapid movements in the air, how can the vocal cords be set in vibration when the air coming from the lungs is passing them in a continuous and steady current? The expiratory muscles, i.e. those of the ribs and abdomen, certainly do not go through 2000 contractions per second, and thus send air from the lungs in as many little "puffs"; yet 2000 per second is the rate of vibration in the air which is required to produce some of the higher tones a person can sing. We all do know, however, that a blade of grass or a strip of paper drawn between the lips will vibrate very

rapidly even though one blows on it steadily. For similar reasons the vocal cords, stretched across the trachea, will vibrate when a strong, steady current of air is sent through them, thus producing air waves which give rise to sound.

**Pitch of Voice.**—The short strings on a piano give out higher tones than the longer ones; but the pitch of any of the strings may be made higher by tightening them. In the

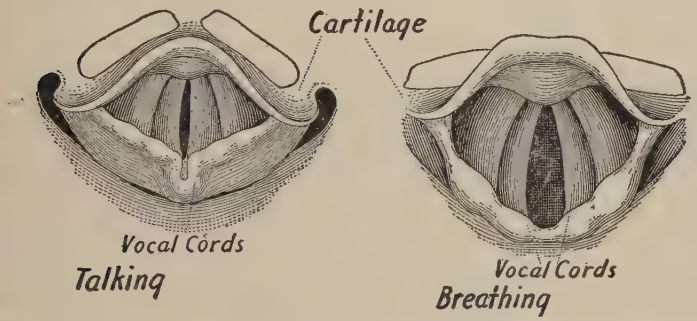



FIG. 107.—THE LARYNX AS VIEWED FROM ABOVE WITH THE MEMBRANES IN POSITION

The figure at the left shows the vocal cords tightened to produce a sound as in talking and that at the right shows them slackened and widely open as in quiet breathing.

larynx, the length of the vocal cords cannot be changed, so pitch must be modified by varying their tension. If the muscles that tighten the vocal cords contract, the cords will give out a high tone; if these muscles relax a little and the opposite muscles (Fig. 106) shorten, the vocal cords will loosen and a lower tone result. Under ordinary circumstances these differences in tension are brought about involuntarily, but in singing, conscious determination of their tension occurs to a certain extent.

**Difference in Voice in Women and Men.**—The reason why the voice in women is so much higher in pitch than it is in men, is that a woman's larynx is actually smaller than a man's. When a boy is about fifteen years of age, his larynx begins to

enlarge, and he goes through an experience called a "change of voice"; at the close of this period the larynx assumes its permanent shape and size, and the voice remains practically the same thereafter.

**Quality of Voice.**—The difference in the " sound " of the voice in different people is due to the shape and size of various air spaces associated with the throat, mouth and nose. The strings taken from the finest violin in the world and stretched from one nail to another in a board would not give out pleasing sound, however they were bowed. In like manner, air in a barrel changes the " sound " of the natural voice when one speaks into it; speaking into bottles of different sizes gives rise to different sounds. The fine tone of an instrument is due more to the vibration of the air inside it than to the strings themselves.

In the same way the character of the voice is largely determined by certain air spaces; by the columns of air in the trachea, in the pharynx and in the nasal passages; by certain air cavities in the bones between the pharynx and the brain, and by others in the bones making up the partition between the nasal passages and the brain; Fig. 96.

These spaces are all of much consequence in determining the finer characteristics of the singing voice, and much of voice training consists in developing the habit of "placing" the voice in such a way as to obtain the best use of these air chambers.

**Loudness of Voice.**—The loudness of the voice is due to the amount of air and the force with which it is driven through the slit between the vocal cords. A piano string which is set in vibration by a very forcible stroke gives out a loud sound; struck lightly, the same string, vibrating through lesser distances, gives out a fainter sound though of the same pitch. In a similar way, the loudness of the voice depends upon the amount of the vibration of the vocal cords, which in turn is determined by the strength of the air current.

**Pronunciation** is effected almost entirely by the shaping of

the mouth and by the use of the lips and tongue. The lips govern all sounds involving *m*, *b* and *p*, the teeth and tongue sounds involving *d*, *l*, *n* and *t;* while the tongue, by its position at back or front, governs to some extent the pronunciation of every word one utters.

The readiness with which one makes himself understood is dependent more upon the clearness of his enunciation than upon the loudness of his voice. Some public speakers shout very loudly and yet are difficult to understand; others speak quietly, but are heard easily. The difference is largely due to the degree of distinctness with which they pronounce the consonants at the beginnings and endings of words. The loud shouting of the vowel sounds renders one's voice less, rather than more intelligible. If one pays a little attention to the proper enunciation of the consonant sounds he will have no difficulty in being understood either in public speaking or private conversation.

## CHAPTER XIV

## THE EXCRETORY SYSTEM

No machine has ever yet been invented so perfect in construction that it will not wear out. Often it is impossible to see with the naked eye the material which wears away from a machine, but we know that it does disappear. The axles of wagon wheels grow smaller, the tires wear away, bolts get loose; all these parts have to be renewed occasionally.

Furnaces do not show the same kind of friction as axles and wheel tires but they require, at times, new piping, grates and valves. In furnaces, too, there is another kind of material which must constantly be removed: the ashes, which are the waste from the burned fuel, must be raked out, or the fire-box will become clogged so that the fire will not burn. From the burning fire, too, a quantity of waste gas goes off up the chimney.

In similar ways, wastes are produced in the human body. The tissues are constantly wearing out, and the parts worn away are useless and must be removed. In the body, too, the oxidation of food leaves waste material corresponding in a way to ashes, and in this oxidation gases are produced, and considerable water. All of this waste must be eliminated, and the general process of getting rid of it is called **excretion.**

### EXCRETORY ORGANS

These wastes are conveyed to the exterior by four main paths: *the lungs, intestine, kidneys* and *the skin.* It is difficult to say which is the most important, for interference with the functions of any one produces serious consequences. Deaths

from lung and kidney troubles are frequent. Death from skin troubles rarely occurs, since the skin is not apt to be attacked over the whole body at once, but it has been discovered that if a person's body is painted over with a varnish that interferes with skin functions, death will inevitably result. (See "Body Temperature," Chapter XV.)

When we speak of the portion of the waste material excreted through the intestine, we do not refer to the undigested parts of the food that simply pass through to be discharged, but to materials actually excreted from the body into this part of the digestive tract. Most of these come from the liver, which, as we have seen, pours quantities of bile into the intestine. This bile aids somewhat in digestion, but is, after all, chiefly a waste product which passes from the body with the fæces.

**Agency of the Blood in Removing Wastes.**—In the building and economy of any great city two systems of piping are connected with every house, and are at the service of every individual: the water pipes which supply the fresh water, and the sewers which take away the waste and the polluted water. To be sure, water could be taken from a well in the cellar of each house, and the waste could be poured on the ground outside; but these practices, sooner or later, would almost certainly cause diseases, if not death, in the house or community. All up-to-date houses are provided with special water supplies and sewage outlets.

In the human body the same system of tubes serves to bring in fresh food and water supplies and to take away the wastes. The blood, which serves both these ends, is thus a very complex liquid. It contains all of the food absorbed from the intestine, and in its circulation it receives all the wastes from the various parts of the body, carrying them away to the organs that are to excrete them. Living involves such constant activity that waste matters are continually thrown into the blood. A certain amount of blood can ab-

sorb only a certain amount of these wastes, but if they can be constantly removed from it, the blood may go on absorbing them continually. A part of these materials, we have already learned, is excreted through the lungs, since there carbon dioxid gas and water are being constantly eliminated, respiration thus being in part an excretion. The wastes excreted through the skin will be considered in a special chapter. The portion secreted through the kidneys will be noticed here.

### UREA: ITS SOURCE AND EXCRETION

Proteid food contains nitrogen; therefore, among the body wastes there must be some which hold this element. The main one is **urea,** which is essentially broken down proteid material, with the chemical formula $(N_2H_4)$ CO. Although muscles are largely proteid this does not necessarily mean that muscular work will result in a large amount of urea formation, for the energy of muscular contraction comes chiefly from the oxidation of starches, sugars and fats; since these contain no nitrogen their oxidation, of course, produces no urea. A considerable quantity of urea does come from the muscles, but this happens whether they are working or not; for the very act of living results in the breaking down of proteid material, and consequently in nitrogenous waste.

The waste from muscles does not leave them as urea, but in a slightly different form. It is probably carried by the blood to the liver, where it is changed into urea. Thus we learn of another function of the liver, viz. in converting this waste from the form in which it leaves the muscles into a form capable of excretion. The proof of this fact is that an animal from which the liver has been removed, or in which it is diseased, gives off very little urea, though an unusual amount of ammonia, which also contains nitrogen, is excreted in such a case. From the liver the urea passes into the blood again, to be carried to the kidneys whose function it is to remove urea from the blood.

The necessity for urea excretion is shown by the fact that all animals, even microscopic ones, have organs for its removal; although these organs are known by different names, in all cases they correspond in function to the human kidneys.

## THE KIDNEYS

The kidneys are located one on either side of the body, in the "small" of the back, a little to each side of the backbone and a trifle below the eleventh pair of ribs, the left kidney lying somewhat higher up than the right; Fig. 108. The peritoneal lining of the body cavity, is stretched tightly over them. They are firm in texture and dark red in color. Figure 108 shows each kidney to be oval in general shape with a depression on the side toward the backbone, thus having a form known as "kidney shape." From the depression a tube, the **ureter,** leaves the kidney and extends downward to the bladder. Close by the exit of the ureter the renal artery enters the kidney and the renal vein leaves it.

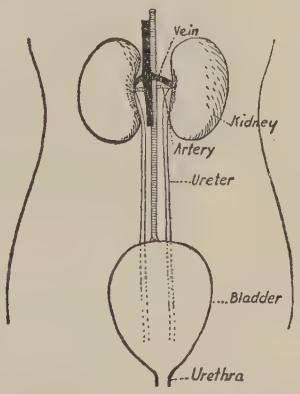



FIG. 108.—DIAGRAM
Showing the position of the kidneys and their connections.

The internal structure of a kidney appears somewhat as in Figure 109. The ureter is large like a funnel as it leaves the organ and is continuous with a space, called the **pelvis,** in the body of the kidney itself. Protruding from the kidney substance into the mouth of this funnel are conical structures of soft tissue, eight to eighteen in number, called the **Malpighian pyramids.** On the apices of these are the openings

of numerous **tubules,** which come from the outer layer of the kidney, the **cortex.** The outer ends of the tubules are the real glands, which produce the kidney secretion; their inner ends drain these glands, carrying their secretion to the pyramids and pouring it into the funnel-like opening of the ureter, whence it runs to the bladder. To understand the structure and action of the kidneys we must study these tubules more minutely.

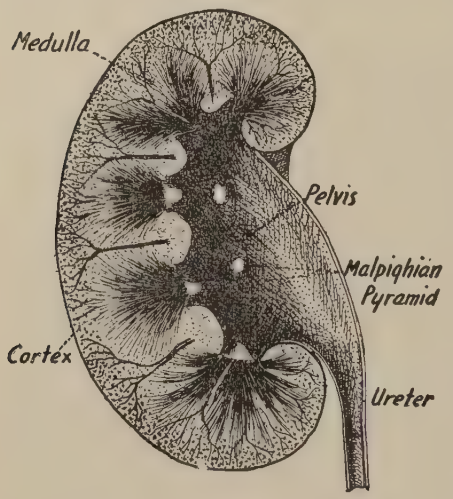



FIG. 109.—REPRESENTING A KIDNEY OPENED LENGTHWISE
(Sappey)

**A Urinary Tubule.**—In Figure 110 a diagram of the arrangement of two urinary tubules is given. Each begins at its outer end, i.e. the end toward the kidney surface, in the form of a bulb-like expansion, the walls of which are only one cell thick. This bulb, the **Malpighian capsule,** is deeply indented on one side, so as to form a pocket. From this pocket, there arises a long tube which takes a somewhat irregular course. It turns toward the center of the kidney, but almost at once becomes twisted into irregular coils, called the **convoluted part** of the tube. Afterwards, it proceeds in a fairly straight line toward the pelvis of the kidney, but goes only a short way, when it turns sharply on itself and returns toward the outer surface of the kidney once more, near where it started. Here it is joined by other tubules of the same sort and together the united tubes now pass as a

single duct in a nearly straight line to the tip of one of the pyramids. There the contents are emptied into the pelvis, whence they immediately enter the ureter.

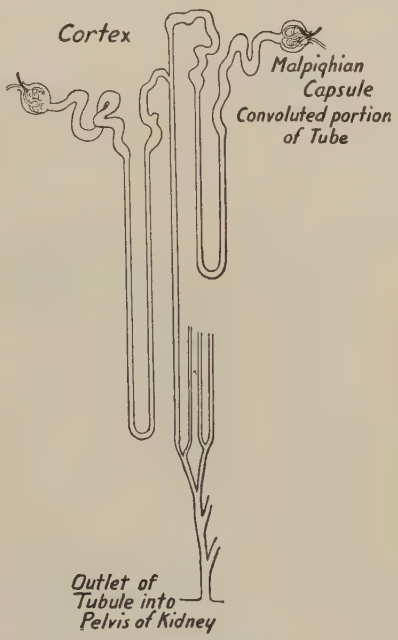



FIG. 110.—DIAGRAM
Showing the course of two kidney tubules. (Huxley)

**The Renal Blood Vessels.**—The distribution of the blood vessels aids us in understanding how these tubules act. The artery enters the kidney at the pelvis, and breaks up into many small vessels which run toward the surface or cortex of the kidney. Here a minute twig enters each of the little pockets at the beginnings of the tubules (Fig. 110), inside which it breaks up into a roundish knot of capillaries called a **glomerulus.** After flowing through the capillaries the blood emerges from the pocket as a tiny vein, but does not immediately flow out of the kidney. A part of it enters at once another set of capillaries that run among the convoluted kidney tubules. After traversing this second set of capillaries, the blood enters definite veins and flows out of the kidney by the renal vein; Fig. 111.

**The Separation of Urea from the Blood.**—We must keep in mind that the main nitrogenous waste, **urea,** is made in the liver from materials in the blood and then returned to the blood stream; and that it is only through capillary walls that blood can expel its waste or absorb new

material. There are, then, two places where material from the blood vessels can be set free into the tubule; through the walls of the capsule which surrounds the glomerulus, and through the walls of the convoluted part of the tubule. By a series of delicate tests it has been found that water and some common salts in solution leave the blood through the walls of the capsule. Although this process is, doubtless,

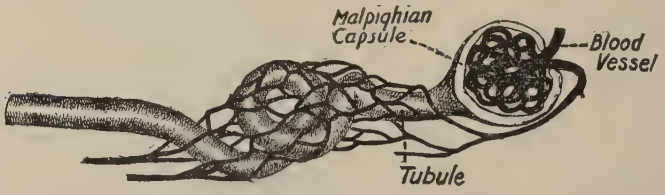



FIG. 111.—SHOWING THE DISTRIBUTION OF THE CAPILLARIES AROUND A SINGLE KIDNEY TUBULE

The blood capillaries in the capsule form a glomerulus.

largely one of filtration, it is unlike ordinary filtering through paper in that not all substances in solution will pass through. The cells of a Malpighian capsule allow some substances to go through, while they prevent others. This, like the absorption of food through the intestinal walls, can only be explained by saying that the cells making up the membranes are alive.

Where the capillary blood vessels spread out over the convoluted part of the tubule, the cells of the tubule are true secreting cells, selecting from the blood waste organic materials, chiefly urea, but also some other substances (*pigment, phosphoric* and *sulfuric acids, sodium, chlorine, ammonia,* etc.). These pass into the tubule; there the water coming down from the capsule dilutes the secretion and carries it into the *pelvis cavity.*

The entire kidney is a compact mass of thousands of these tubules, each having an irregular course and each opening into the reservoir of the pelvis. Inasmuch as the **cortex** is so richly supplied with blood capillaries, this surface layer is redder in appearance than the deeper parts which border on

the pelvis. This latter **medullary region** is made up for the most part of larger blood vessels, connective tissue and collecting tubules.

The blood that flows out of the kidney by the renal vein is the purest in the body. It is arterial blood containing considerable urea when it enters, but in flowing through the kidneys the urea and some other wastes are removed, so that it flows out actually purer than when it entered.

**Urine Excretion.**—The rate at which the kidneys excrete *urine* is very variable, depending largely upon conditions of the air one breathes. More is excreted in cold weather than in warm, and more in wet weather than in dry. In hot, dry weather so much of the water waste of the body leaves it in the form of perspiration that less is passed off through the kidneys. Certain foods and drugs, the drinking of a great quantity of water or other liquids, and nervousness are all agents which may alter the rate of secretion. The rate at which the *urea* is secreted is not, however, dependent upon these factors. It is dependent simply upon the rate of its formation in the body. If formed rapidly, it is excreted rapidly, even though the total amount of urine is small. The rate of urea formation is dependent upon the rate at which proteid material is broken down in the body, and the kidneys will eliminate this urea as fast as it is brought to them by the blood. An average daily amount of kidney secretion is three pints.

**The Ureters.**—The ureters, which receive the urine from the kidneys, are small tubes of about the diameter of a good sized quill. Internally, they are lined with a mucous membrane, outside of which muscles are arranged, essentially as in the intestinal walls. By their peristaltic contraction these muscles force the urine downward into the **bladder**.

**The Bladder.**—The bladder, Fig. 108, is the reservoir for the temporary storage of the urine, and is located in the middle of the abdominal cavity, in front of the rectum. It

is an oval sac and when moderately full is about five inches in vertical measurement and three inches across, holding about two thirds of a pint. The muscle fibres of its walls are smooth extending in every direction about it, so that when they contract during the process of emptying, the bladder shrinks in all its dimensions.

**The Urethra.**—The single tube which leads from the middle of the lower end of the bladder to the exterior, is called the **urethra.** The opening from the bladder into it is ordinarily closed by strong circular muscles passing around the tube at its point of exit. These muscles stay in a condition of constant, involuntary contraction most of the time, relaxing only on receipt of a special message from the brain.

**The Need of Drinking Fresh Water.**—In the chapter on foods we learned that the body needs a constant and large supply of water. The necessity for plenty of water in dissolving and removing body wastes through the kidneys furnishes one of the chief reasons for this. Most of the water that flows through the kidney tubules must come originally from the water we drink. If plenty is supplied, the whole liquid content of the blood can be more easily kept in solution, and more water can be given off in the urine to "flush" the system. The sewers of a city must never be of too small capacity and they must never become clogged; water must be kept running abundantly in them to prevent solids from settling and decomposing; otherwise, pestilence and disease set in. Similarly, every organ and cell in the body must have plenty of liquid blood flowing through and past it to furnish fresh supplies, and to receive all the wastes, liquid, solid or gaseous.

## GENERAL SUMMARY OF METABOLISM

Since urea represents the form in which all the nitrogen of the proteid material in our food leaves the body, the whole process of metabolism may be appropriately mentioned here. In an earlier chapter the definition of the term metabolism

showed it to be the series of changes by which simple inorganic matter is built up into complex organic matter, and all the consequent changes by which it is broken down again into simple elements.

With the foregoing study of kidney excretion, the story of metabolism is nearly complete. It begins with the life of plants that take carbon, oxygen, hydrogen and nitrogen from simple gaseous and mineral sources, and build them up into proteid, carbohydrate and fatty compounds. Man, by eating plants, converts these into animal proteids, carbohydrates and fats. To be sure, some of his foods come directly from other animals, but even these come originally from plants. After performing various functions as animal tissue in the body, food is broken down and excreted. Much of it leaves the body as carbon dioxid gas and water, reduced thus to the condition in which plants originally obtained it. Part of the food leaves the body as urea and part of it remains in the body. Later, the urea secreted as well as the tissues of the dead body undergo a further set of decomposition changes. They are attacked by a host of microscopic organisms (bacteria and molds) causing further and more complete breaking down. These processes are called *fermentation, decay* and *putrefaction*; but it should be remembered that these are simply names for the final steps in the decomposition of food materials. At last they are brought once more into the same condition as that from which they started, so that a new generation of plants can feed upon them. *The whole process is a cycle,* the same materials circulating around in an endless succession from soil and air to plants, from plants to animals, from animals back again to the soil or air, partially through the agency of bacteria, to start again on their round of usefulness

## DISEASES OF THE EXCRETORY ORGANS

Excretion of the wastes of the body is absolutely necessary. If anything interferes with the action of the kidneys, the

body becomes rapidly poisoned by the accumulation of urea in the blood.

**Bright's Disease** is a name which really covers a number of different diseases but they are all characterized by an interference with the power of the kidneys to excrete urea and other wastes. One of the earliest symptoms is usually the appearance of considerable albumen in the urine. In a healthy condition the urine contains no albumen and its appearance is always an indication of faulty metabolism. Although Bright's disease is dangerous, recovery from certain forms of it is frequent.

**Kidney Stones.**—In another disease of the excretory organs, hard, little nodules, called **kidney stones** or **calculi,** form in the pelvis of the kidney and pass down into the bladder. They are apt to cause severe pains as they go through the ureters and sometimes cause alarming symptoms. Usually, if properly treated, they do not produce much trouble, and sometimes they pass away with the urine. In some severe cases, however, a surgical operation is necessary for their removal.

**Diabetes** is the name given to a disease in which sugar appears in the urine, the normal urine containing none. It is not, however, a disease of the kidneys, although the trouble is detected in the secretion from these organs. It is due rather to improper nutritive processes in the body, although the exact seat of the trouble has not yet been determined. An individual suffering from this disease is unable to assimilate his foods properly and there seems to be especial difficulty in the assimilation of sugar. This results in an excessive amount of such material in the system and the kidneys are obliged to excrete it. Diabetes is a very serious disease, and recovery from it is rare.

**Jaundice** is a term used to denote symptoms of some derangement of the liver, because of which it is failing to carry on its proper functions in connection with excretion.

The actual cause is not known, but the symptoms are striking. The disease is characterized by a noticeable yellow hue of the skin and very dark urine. The colors are sometimes so deep as to be alarming, but the trouble is not serious as a rule, and soon disappears. The real cause of none of these several diseases is as yet known. They do not seem to be produced by disease germs, and none of them are contagious. No methods of avoiding them are known beyond the general one of maintaining good health by proper exercise and diet, avoiding overeating and stimulants.

## CHAPTER XV

## THE SKIN

The skin is not ordinarily considered an organ of much importance. It seems to be merely a covering for the body and it is not at first easy to believe that the skin actively functions. In reality, it is an important organ which performs some of the most vital offices in the human body. There is no part of the body which has more to do with one's comfort than the skin; and there is almost no part whose sluggish or improper functioning leads to more general unpleasantness or is more liable to induce illness.

### STRUCTURE OF THE SKIN

The skin is a sheet of tissue covering every part of the surface of the body, except the eyeballs, and even these when the eyes are closed; there are a few large openings through it for the entrance and exit of solid matter. The skin is about $\frac{1}{16}$ of an inch thick, but it varies considerably, being much thicker on the soles of the feet and palms of the hands than elsewhere. If a thin section of the skin is examined under a microscope it will be seen to consist of two distinct layers, an outer called the **epidermis,** and an inner called the **dermis.** The epidermis is lifeless, save for a thin layer on its inner surface, and can be cut without pain or bleeding; the dermis is extremely sensitive, full of nerves, blood vessels and glands; Fig. 112.

The difference between a plump person and a slender one is also manifest in the skin appearance generally, for in the former much fat, called adipose tissue, is often present among the glands and connective tissue of the dermis.

The skin is quite elastic and is really somewhat larger than is necessary to cover the body. If it be seized by the fingers almost anywhere, e.g. on the back of the hand, it can easily be lifted into a fold, but returns to its original place when

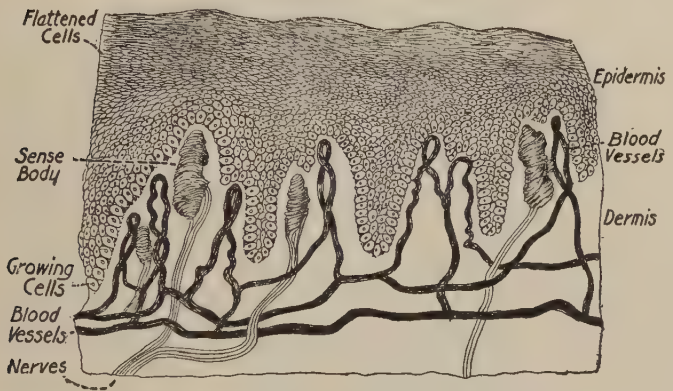



FIG. 112.—SECTION THROUGH THE SKIN
Showing the layers of the epidermis and the sense organs and blood vessels of the dermal papillæ.

released. On account of this elasticity it readily accommodates itself to the shape of the body, and is ordinarily stretched smoothly over it. As a person grows older, it becomes less elastic and is finally thrown into wrinkles.

### THE EPIDERMIS

The inner surface of the epidermis is composed of a layer of **growing cells,** somewhat rounded in shape; Fig. 112. They are nourished by the blood from below, and are constantly multiplying and growing. As they increase in numbers the new cells push the older ones toward the outer surface of the skin, and the epidermis is thus made thicker by growth in its deeper layers. As soon as the cells are pushed away from the deep, growing layer, they cease to have life

and gradually become flattened by pressure. The skin is always wearing away at its surface because of the constant friction it receives. Débris resulting from this wear is not ordinarily noticed, but when it accumulates in the hair, along with the dried secretion of certain skin glands, it is called **dandruff.** After scarlet fever, measles, etc., the epidermis may come off in sizable flakes.

Some of the deeper cells of the epidermis contain **pigment** matter which gives the skin its color. This pigment differs in the skins of different races; in the negro it is abundant and black; in the yellow races it is of a brownish yellow color; in the skin of the white races there is very little, but here, too, it varies slightly in amount, producing differences in complexion, e.g. blonde and brunette. **Freckles** are due to the unequal distribution of this pigment which may be especially dense in spots; they are frequently produced in children by much exposure to sunshine or cold winds.

**Thickened Parts of the Epidermis.**—Wherever there is more than the usual amount of wear, the epidermis grows more rapidly and becomes thicker than elsewhere; examples of this growth are seen in the **callouses** on the hands and feet. If the rubbing is not severe but long continued, the epidermis grows into prominences called **corns** or **bunions. Blisters** result from a sudden rubbing of the skin, the capillaries being stretched and lymph collecting between the dermis and epidermis in consequence.

**Skin Grafting.**— The only way in which epidermis grows is by multiplication of the cells in its deeper layers. When these growing cells are destroyed over a large area, e.g. after severe burns, it may be difficult for the epidermis to be reproduced. If a bit of epidermis is taken from a healthy part of the body, or from some other person, and firmly placed upon the raw surface of such a wound, it will generally grow there, extending rapidly and eventually covering the surface which would not otherwise have healed. Such a

procedure is called **skin grafting** and in modern surgery is a common practice of dealing with slowly healing wounds, especially wounds from burns.

**Hair.**—To the naked eye hair appears unlike any other part of the skin. Throughout most of its length, hair is dead and shows little structure; but near the root where still alive it is made of cells like all other organic material. If a

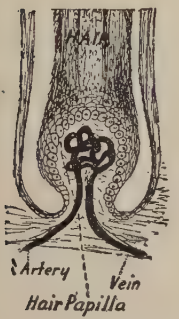



FIG. 113.—SECTION THROUGH THE BASE OF A HAIR
Showing its different layers, the papilla upon which it grows and the blood vessel that nourishes it.

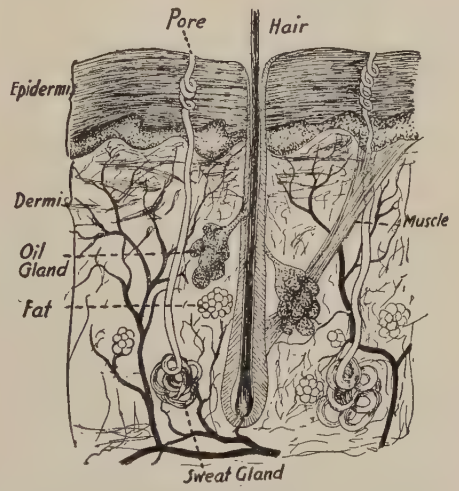



FIG. 114.—SECTION THROUGH THE SKIN
Showing the various organs in the dermis and epidermis.

hair were split and examined under the microscope, its appearance would be something as in Figure 113. In the center is a kind of pith called the **medulla** of the hair; next this is a horny layer, the so-called **cortex,** in the cells of which is the pigment determining its color. Outside the cortical layer is the **cuticle** of the hair, a transversely arranged series of horny cells, each upper row overlapping the one below it like the shingles of a roof. Each hair comes out of a sac, or hair

**follicle,** a tiny canal of epidermal cells extending down into the dermis; Figs. 113 and 114. The lower end of this follicle is enlarged and projecting upward into it is a **papilla** on which the hair grows. Cells of this papilla are constantly multiplying and turning into hair substance and thus the hair lengthens. After a time (in the scalp, perhaps three years), the top of the papilla ceases to form new cells, the hair dies and falls out. Before this occurs, however, a new papilla has been budded off the side of the old one and from it a new hair starts. When a hair is pulled out the epidermal cells lining the follicle may come away also, but the papilla usually remains uninjured and a new hair soon grows from it. The straightness or curliness of hair depends on its shape: kinky hair is flat or oval in cross section; wavy hair is oval; while straight hair is round and rod-like.

Emptying into each hair follicle is usually an **oil** or **sebaceous gland**; Fig. 114. These glands secrete a substance which moistens the surface of the hair and keeps it soft and flexible. To the lower end of the follicle in most hair-bearing animals is fastened a slender **muscle,** its other end being attached to the lower layers of the epidermis; Fig. 114. The shortening of this muscle pulls the follicle into a more vertical position, making the hair "stand up straight," as a cat's fur frequently does, for example.

All epidermal structures are disturbed and cast off to a greater or less extent in the case of some fevers, and not infrequently the hair falls out after a long sickness.

Hair itself is not sensitive, though if it is stiff one may feel a very slight touch upon it because of the presence of nerves in the dermis at its base. The stiff hairs around the nostrils of a cat are thus sense organs of touch. Over most of the human body, hair remains so short as to be almost invisible and of only slight protective value. The tendency for hair to fall out and leave the head bald is probably due in part to the bad habit of wearing hot, heavy hats with stiff rims which bind the scalp.

**Nails.**—The **finger** and **toe nails** are especially thickened parts of the epidermis. Figure 115 represents a lengthwise section through the tip of the finger, showing a nail. It grows chiefly at its base, called the **root,** and as it grows its free end is pushed out farther and farther. It also grows thick by additions to its under surface. The reason why a nail appears whiter at its basal end is that blood capillaries are less plentiful in that region than elsewhere; this "white" of the nail is technically called the **lunula.**

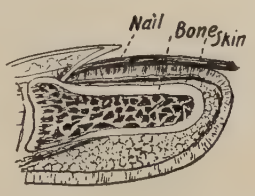



FIG. 115.—SECTION THROUGH THE END OF A FINGER
Showing the relation of the nail to other parts.

## THE DERMIS

Below the epidermis is a live layer composed of connective tissue, nerves, blood vessels and fat. It is largely made of a dense mass of connective tissue fibres like the material we have already noticed in tendons and ligaments, except that in skin it is arranged in a much looser mass; the fibres run in every direction, are closely packed together near the epidermis, but below, near the muscles, become quite loose; Fig. 114. In the spaces between the fibres are masses of fat cells which fill out the skin and make the body appear rounded. If these layers of fat were not there, the skin would cling tightly to the flesh so that muscles and tendons would show through it. When a person is insufficiently nourished, as for example after a long illness, the location of the separate muscles beneath the skin is plainly seen because the fat stored in the dermis has been used.

The dermis is full of blood vessels. This is most evident on certain areas, e.g. the lips and inner surfaces of the eyelids, where the epidermis is very thin and the capillaries of the dermis show through, giving these areas their red appearance.

The outer surface of the dermis, where it comes into contact with the epidermis is not flat and smooth but shows many small elevations, called **papillæ**; the epidermis fits over these so that the two layers dovetail into each other; Fig. 112. These papillæ on certain parts of the body, e.g. on the palms of the hands, are arranged in parallel or concentric rows so that they show through the epidermis and produce the fine lines which appear on the tips of the fingers and toes.

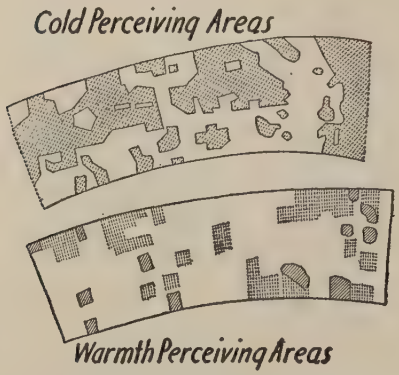



FIG. 116.—DIAGRAM
Showing the areas on the back of the hand that perceive heat and cold. The two figures represent the same area, one figure showing the cold and the other the heat perceiving areas. (Goldschneider)

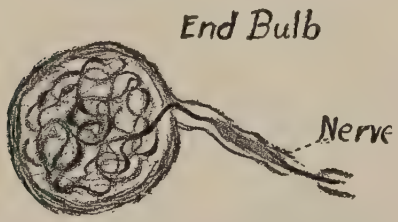



FIG. 117.—ONE OF THE END BULBS OF TOUCH IN THE EYE
(Dogiel)

**Organs of Touch, Heat and Cold.**—In these papillæ, nerve endings and blood vessels are abundant, though the same papilla does not usually contain both. Some nerve endings associated with touch and temperature changes are shown in Figure 112. A number of endings in the same region will perceive only cold, others only warmth; so that in general we may say that the whole body is mapped out into " cold and warm spots "; Fig. 116.

The ends of nerves which are sensitive to touch are called **tactile corpuscles** or **end bulbs**; Figs. 117 and 118. They are of different shapes and extremely small, varying for the most

part from $\frac{1}{800}$ to $\frac{1}{600}$ inch (0.04–0.08 mm.) in diameter.

The sense of touch may be one of mere pressure, or when excessive may be that of pain. Naturally, those parts of the body are most sensitive where the papillæ which contain these nerve endings are most numerous. The tip of the tongue has the most nerve endings to a given area, and the finger tips are the next most sensitive organs. Nerve endings are farthest apart on the back, and on the back of the neck. Two points one tenth of an inch (2.5 mm.) apart can be identified as two if they are on the finger tips. In the middle of the back, however, two points two and a half inches (66 mm.) apart may be felt as one.

FIG. 118.—A TACTILE CORPUSCLE FROM THE FINGER (Ruffini)

**The Skin as a Protecting Organ.**—The skin is a protection against the entrance of disease germs. The many overlapping layers of epidermis cells form such a thick mass that bacteria cannot penetrate it and reach the living parts within. If it is broken, however, bacteria can attack it at once. The need of thoroughly cleansing skin wounds is thus manifest.

Any of the common antiseptic washes or lotions are of some value, but especially those containing formalin (3-10% is very effective), bichloride of mercury (1 part in 1000), or carbolic acid (2½%), are effective, easily used, and inexpensive. If certain treatments cause sharp pain for a few minutes, this is a good indication, for it probably means that the naked tissue is being killed, with the bacteria on it.

## THE SKIN AS AN EXCRETING ORGAN

The skin secretes perspiration at the rate of one to five pints per day. This quantity varies according to the amount

of exercise a person takes and the condition of the air about him. One perspires less on a wet day than on a dry one, and less in cold weather than in warm. Ordinarily this secretion is produced so slowly that it evaporates as fast as it is formed and except for a realization that the skin is kept moist and flexible, one is unconscious of it. When the glands secrete very rapidly, their output may not evaporate as fast as it is formed, and collects in small drops; this occurs particularly when the weather is hot, or when one is exercising vigorously. Physiologists speak of this "sweat" as *sensible perspiration*, while the ordinary slow secretion is called *insensible perspiration*.

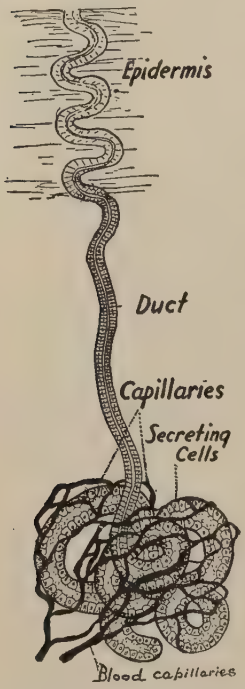



FIG. 119.—DIAGRAM Showing a sweat gland, its duct and its blood supply.

The amount of insensible perspiration increases with a rise in temperature, from a cold state up to about 92°F; a very sudden increase in the perspiration rate then sets in, and sweat drops collect on the skin; at the same time, $CO_2$ is eliminated in considerable amount through the skin. In this connection it is interesting to note that in some animals, e. g. the earthworm, frog, etc., the skin is the principal breathing organ.

**Sweat Glands.**—There are about two and a half million sweat glands scattered through the dermis of the human body. They occur in least numbers in the middle of the back, where there are about four hundred per square inch, while on the palm of the hand and sole of the foot there may be two thousand five hundred in the same area. Each sweat gland is a minute tube of uniform diameter, closed at its inner end where much of its length is coiled into a knot; Fig. 119.

The cells which constitute this part of the tube are the true secreting cells, and this glandular portion is surrounded by a net-work of blood capillaries. The ducts from different glands do not join one another, but each passes nearly straight up through the dermis, then through the epidermis in a wavy course, to open by a minute pore on the surface of the skin. The pores are too small to be seen with the naked eye, but are easily visible if the skin is examined with a good lens.

Like the other glands in the body sweat glands are under the control of definite nerve fibres, called **secretory nerves.** These are stimulated by various means; by reflex influences when strenuous muscular work is being performed; by the condition of the surrounding air; by fright or by special conditions of the internal organs. Like other glands, too, their action is not within control of the will.

**Functions of the Sweat Glands.**—The sweat glands have two very important functions: (1) **Excretion of water and other materials.** Large amounts of perspiration, which is water in great measure, are secreted daily, thus making the skin second only to the kidneys in regulating the amount of water in the blood. There are also small amounts of various salts, traces of fat and other substances in perspiration. If on account of a disease of the kidneys, urea cannot be properly excreted from them, it may be partially disposed of through the skin, which thus helps to purify the blood. (2) **Regulation of body temperature.** This is a matter of such importance that it must be discussed in considerable detail.

## BODY TEMPERATURE

The life processes in all animals and plants are closely related to temperature. At the freezing point all their activities stop; at temperatures slightly above this they begin and with increase of temperature become more vigorous. For the human body 98° F. seems to be a very favorable temperature. Even the simple functions of digestion are checked

by temperatures markedly lower or higher than this; and it follows, therefore, that the greatest vigor is possible only when the body is warm.

Not only is the body warm but it is kept at an almost uniform temperature. This varies slightly in different persons, and in the same person different parts of the body show slight variations from the average of 98.6° F. The internal organs are considerably warmer than those on the surface; the temperature of the skin itself is not much over 90° F., while that of the liver may be as high as 107° F. Moreover, the body heat differs a little from hour to hour, being greatest between 1 P. M. and 4 P. M. and least between 1 A. M. and 4 A. M.

Health is so dependent upon the maintenance of proper body temperature that if there is much departure from the normal, illness results. If the temperature rises to over 100° F. we say that the individual concerned has a fever; a slight fall of temperature below 98° F. is an equally sure indication of illness, though we have no special name for this condition and less commonly hear about it. During a high fever a person's temperature may rise to 106 F. or even a little higher, and recovery take place, but a rise to 107° F. or 108° F. is usually followed by death.

*The source of all body heat is the oxidation of foods.* All body activity involves the oxidation of food or tissues, and thus is necessarily accompanied by heat production. This explains why we get warm when exercising vigorously, why we like to move around quickly on a cold day, and why we need extra clothing when not exercising. We must not, however, confuse *feeling* cold with *being* cold. On a cold winter day one feels much colder than on a warm summer one, and it is hard to believe that the body temperature is practically the same in the two instances. One's feeling of warmth is in the skin; if the blood vessels in the skin are open so that much warm blood can flow through them, one feels warm;

if they are partly closed so that the blood is kept inside the body, one feels cold.

The larger part of the heat of the body is produced in the muscles when they contract, though a great deal seems to be formed in certain glands like the liver. This heat warms the blood flowing through these organs. Then the blood goes to the cooler parts of the body, warming them in much the same way as hot water warms the different rooms of a house, as it goes to them through pipes from a heater. The blood thus distributes, but does not produce heat.

**Cold and Warm-Blooded Animals.**—The **cold-blooded** animals—frogs, alligators, lizards etc.—are never much warmer than the air in which they live. While oxidation of course takes place in them as in other animals, and heat is thus produced, there seems to be no special regulation of body heat, and they have a very low temperature on a cold day and a high temperature on a hot day when lying in the sun. They are apt to be sluggish at any time, but are sure to be so in cold weather.

In **warm-blooded** animals, i. e. birds and mammals, the amount of heat produced is always great, and the temperature of the body does not change with the temperature of the air but remains constant if the animal is in uniform health. Such animals are called warm-blooded because their blood is generally warmer than the air, although on a hot summer day it may be cooler than the air. To maintain a constant, high temperature a considerable amount of heat must be produced and consequently a large amount of food must be oxidized. Warm-blooded animals thus demand much more food than cold-blooded. A turtle's activities are so slight that the little energy stored in its body is sufficient to keep it alive for six months without food while a warm-blooded animal must have a large supply of food, and can live only a comparatively short time if deprived of it.

**The Regulation of Temperature.**—The temperature of the

body can evidently be modified either (1) by *changing the amount of heat produced*, through an increase or decrease in the amount of food oxidized; or (2) by *varying the amount of heat lost*. Each of these methods is adopted in part; but under ordinary conditions it is by controlling heat loss that this regulation is chiefly effected. To appreciate this fact it must be understood that the heat resulting from the ordinary oxidation of food is *more than enough* to warm the body and keep it at 98° F. To maintain the correct body temperature, therefore, it is necessary that some heat be passed off.

**Loss of Heat through the Lungs.**—When the temperature of the air is considerably lower than that of the body, as is usually the case, one loses superfluous heat in breathing. The inhaled air is cooler than the body, but when exhaled its temperature has been raised. Of course, if the air has thus been warmed the body has been correspondingly cooled. The cooler the air breathed the more heat it will take from the blood. On a cold day so much heat may be lost by this means as to take away nearly all the surplus; but when the air is warmer this loss is not sufficient for the purpose of keeping the body temperature uniform.

**Loss of Heat from the Skin.**—The chief method of regulating body heat is by the expansion and contraction of the blood vessels in the skin. Since the air is almost always cooler than the blood, blood will, of course, be cooled as it flows through the skin; and the more rapidly the warm blood flows through the skin, the more rapid will be the loss of heat. But while this swift flow actually cools the body, it seems to make it warmer. This is due to the fact that the skin is very sensitive to temperature, and when an extra amount of warm blood is flowing through it a feeling of extra warmth will be experienced, though the body is actually cooling.

One often feels this to be true when a sore finger is bandaged and a string tightly tied about it; the end of the finger feels cold because free movement of the blood has been prevented by the

ligature. A rubber band tightly wound on the finger gives similar evidence of the same fact.

**Expansion and Contraction of Blood Vessels in the Skin.**—We have already noticed how readily the small blood vessels are expanded and contracted by the action of muscles in them and that this action is controlled by nerves. In the skin the muscles in the small arteries are especially well developed and quickly relax or contract under the influence of extra heat or cold. If the temperature of the air rises on a warm day, if the body is warm, or if extra heat is being produced, the blood vessels in the skin relax. In short, whenever the heat being produced in the body is greater than that required to maintain the proper temperature a relaxation of the skin vessels allows more blood to come to the surface, thus increasing the loss of heat. Whenever heat loss from the skin is greater than heat production, so that the body is cooling too rapidly, the skin vessels contract and allow less blood to flow through them. This keeps the warm blood inside, and, of course, prevents the body from cooling too rapidly. The perfect control which the brain thus has over these vessels enables it to regulate the amount of blood flowing through the skin and, consequently, the amount of heat lost through direct radiation from the body.

**Perspiration as a Heat Regulator.**—There is another means by which loss of heat through the skin is regulated. The sweat glands are constantly pouring their secretion upon the skin, where it is as constantly evaporated. It is a simple law of physics that heat is required to evaporate moisture. Hence the larger the amount of sweat poured upon the skin for evaporation, the greater will be the amount of heat required for evaporating it, and therefore any increase of perspiration increases the heat lost by this means. Everyone knows that the amount of sweat increases with the temperature. On a hot day one perspires profusely, and on a cold day imperceptibly. All these sweat glands are supplied with

nerves in such a way that the brain can increase or decrease the amount of their secretion. When the air becomes so warm that it is difficult for the skin to lose by simple radiation an amount of heat sufficient to keep the body temperature at its proper point, the sweat glands increase their action. In the evaporation of the extra moisture thus poured out on the body surface so much heat is lost that the body temperature is reduced to its proper level.

After a bath, even though the water used be warm, and the room at more than usual temperature, this same sense of coolness is felt. People often say while swimming in a river or the ocean, "The water is warm enough but the air is chilly."

The extent to which body heat may be reduced through sweat evaporation is really very great. One experimenter found that he could remain for some time in a room in which the air was warmer than 260° F. and in which the direct effect of the air would be, of course, to warm the blood rather than cool it. But evaporation of the profuse perspiration resulting took so much heat from his body that he found it perfectly possible to retain his normal temperature. Stokers on ocean steamers, living and working as they do in a temperature of over 130° F., are evidence that this principle admits of constant and daily application. The fact that a fever is accompanied by the lack of perspiration, partially explains the rise in the temperature of the body at such times.

### SUMMARY OF METHODS OF HEAT REGULATION

As an illustration of heat regulation in the body, imagine a hot summer day with the temperature of the air over 100° F. The air is actually warmer than the body; the sweat glands pour out an abundant secretion which rapidly evaporates. This evaporation cools the skin and *reduces the temperature* of the body to the desired point.

Suppose the temperature of the air falls to 85° F. Profuse sweating ceases; perspiration does not stop, but the sweat is less abundant, does not collect so profusely in drops, and a different method of controlling body heat comes into play. The blood is now warmer than the air, and will be cooled as it flows through the skin; owing to the heat, the skin vessels remain relaxed and large amounts of blood from the internal organs are coming to the surface. The skin is thus filled with warm blood and the person still feels warm, though the blood is being cooled by the air. *Heat thus passes off* by direct radiation in sufficient quantities to keep body temperature at the proper point.

Suppose now that the temperature falls to about 70° F. Sensible perspiration stops entirely; the blood vessels of the skin partly close so that less warm blood flows through them; the body *retains its heat* in this way, and its general temperature remains the same as before. If the external temperature falls still more, a different adjustment is necessary. The skin vessels constrict still further, and the warm blood is confined to the internal organs until they are almost oversupplied with blood. Now since so little blood is flowing through the skin, the person begins for the first time to feel chilly, and it is at this temperature, i.e. between 70° and 60° F., that one is most liable to take cold. If the temperature falls yet lower, more *heat must be produced* by increased oxidation. Thus at temperatures above 70° F. regulation of body heat is brought about by increasing or decreasing the loss of heat; below this, chiefly by increasing heat production.

It is important to realize the significance of a constant body temperature; man can exist only while warmth is assured and if its supply were not regulated, he could live only in certain climates. Because of this automatic control of body temperature man can live in summer or winter, in the cold regions of the north, or in the hot climate of the equator.

Animals with an abundance of hair do not perspire pro-

fusely, and their skin has little power of regulating temperature. Such animals must depend largely upon respiration to rid themselves of surplus heat. This explains the panting of dogs, and their rapid breathing in hot weather or when exercising rapidly.

### CARE OF THE SKIN

To insure the healthful functioning of the skin, the pores of the sweat glands must be kept free and open. The fat glands connected with the hair follicles are constantly exuding a certain amount of oil, and the sweat glands give out much water, salts and other substances. The water will readily evaporate, but the solid material will remain on the skin, tend to clog the pores, check the ready action of the glands and cause an offensive odor. Evidently the normal action of the skin demands that this material be removed. To keep the pores open, habitual bathing and washing of the skin is a necessity. The frequency of the bath, however, is a matter in regard to which no rule can be given. A daily bath is certainly desirable, though doubtless not necessary to health.

It is a mistake to suppose that cleanliness is the primary benefit to be derived from bathing, although it is an important one. The principal effect of the bath is in stimulating the skin, and increasing its activity. The skin is a delicate organ, in which more blood is exposed to the air than in any other organ in the body. A large part of one's communications with the outer world are received through it.

**Cold Baths.**—The first effect of a cold bath, whether it be a plunge in cold water, a shower bath or merely a sponge bath, is to stimulate the temperature nerves of the skin, producing a decided sensation of cold. This acts through the brain and causes (1) a contraction of the blood vessels in the skin; for a short time the skin becomes white and cold, due to this contraction. But this is presently followed by (2) a reaction; almost immediately the brain withdraws its contracting in-

fluence allowing the vessels to expand. More blood now flows through the skin, it becomes flushed and warm, and there is a feeling of exhilaration in the body. This " after-glow " may last a long time, and the person should leave the water while still under its influence. If he stays in longer, the blood vessels may again contract, making him chilly, and since this time there is no subsequent reaction to warm the body, he is likely to be cold and uncomfortable for many hours. The length of time that the after-glow may continue depends upon the person, the temperature of the water and to a certain extent upon its character, lasting longer if the water is salt, than if fresh.

The after-glow from a cold bath is increased if it is accompanied by a vigorous friction of the skin. Energetic rubbing with a rough towel is of as much value as the bath as a stimulant for the skin, and without it the bath accomplishes only half its purpose. Rubbing with towels pulls to a slight degree on every part of the surface, stretches the different tissues in the dermis, dislodges any loose epidermis, and leaves the skin alert and ready to perform its duties. In short, the cold bath and the " rub " are to the skin what the gymnasium is to the skeletal muscles.

Since one of the chief objects of the cold bath is to shock the skin, there is no reason why one should not take a plunge into cold water, even when hot and sweaty, provided he does not stay in long enough to become chilled. The shock is an advantage, the cooling is refreshing. On the other hand to take a cold plunge when one is already cold is neither pleasant nor profitable, unless it is followed at once by a vigorous friction which develops the proper after-glow. Cold baths should always be taken when one is warm, e.g. when just out of bed or after vigorous exercise. After a night's rest in a horizontal position, the heart is beating slowly, blood is flowing sluggishly and nerves are stupid. A cold bath at such a time is the best stimulant a person can take to get

himself thoroughly awake, arouse his nerve centers and start the human machine going for the day.

**Hot Baths.**—There are times when hot baths are desirable. Warmth is sure to produce an expansion of the blood vessels of the skin, and thus to a certain extent draw blood from the internal organs. This may be very beneficial; for example, it may enable one to get to sleep, or rest when restless, since it draws blood from the brain. When one has the first symptoms of a cold, a hot bath, or even heating the feet in hot water, may withdraw the blood from the inflamed throat or nasal cavities and check the onset of the cold. This method of causing the expansion of the vessels is not so good an exercise for the skin as the cold bath, and is not really an invigorating stimulant; it tends to leave the skin soft and delicate, and the body should be warmly covered after such a bath, and not exposed to any chill. Hot baths should never be taken immediately after meals, for the blood rushing to the skin to fill the relaxed capillaries is taken from the digestive organs which then need it. Skin activity is the best guard against the various skin diseases. A skin kept healthy by bathing and friction will ward off many an attack of parasitic bacteria to which an unhealthful skin would yield.

## CLOTHING

Much contradictory advice is given concerning the kind and amount of clothing it is best to wear. Fortunately the body so easily adapts itself to conditions that it can get along with many differences in method of treatment. While specific rules for clothing cannot be given, certain principles are involved.

Clothing serves two purposes: (1) to conserve warmth, and (2) to absorb the perspiration of the body. The amount of warmth that any fabric seems to give is dependent not only on its thickness, or weight, but also upon the size and number of air spaces in the cloth. Air is a very poor conductor

of heat and cold. Coarse cloth in the meshes of which are numerous air spaces is, therefore, warmer than closely woven cloth of equal weight. For the same reason, two or more thicknesses of cloth are warmer than one of equal weight, the air space between the two holding the heat.

If we were to live out of doors in the winter, much heavier clothing would be needed than in warm weather; but most of us spend the greater part of our time in rooms whose temperature is very little colder than that of summer and although we do go out into the cold, a comparatively small amount of our time is thus spent. For most people, therefore, it is plainly a mistake to dress the body warmly all the time because of the occasional minutes spent outside. The wiser method is to wear the same amount of clothing that one would wear at those seasons when the outside temperature is about the same as that maintained in one's living rooms in the winter, and then to add upon going out of doors such clothing as is necessary for comfort. If one lives out of doors much of the time in winter the case is different. The amount of clothing needed for very cold weather varies much with different people, depending largely upon whether one has invigorated his skin or has allowed it to become sluggish. One should remember that the primary reason he wears heavy clothing in winter is for comfort and not to prevent taking cold. Indeed, an increase in exercise is a far more efficient means of meeting an ordinary winter's cold than is the practice of bundling the body heavily with wraps. Most people make the mistake of wearing too much clothing in winter, thus reducing their powers of resistance.

The clothing worn next the skin should be of a character to absorb the water of perspiration readily. Cotton cloth is an excellent absorbent and gives the water off again readily. Woollen, which does not absorb water so readily and is apt to hold it without allowing sufficient evaporation, should not be worn next the skin at times when perspiration is abundant.

In summer weather underclothing should be of cotton or of some good absorbent material rather than of wool. In winter when the amount of perspiration is less and its evaporation from the skin a matter of much smaller consequence than in summer, woollen underclothing is not unwise, although cotton is entirely suitable. If one passes most of his time in winter in highly heated rooms, he should wear the same kind of underclothing that he wears in the spring and fall.

### BURNS AND FROSTBITES

Although burns and frostbites are extremely common injuries to the skin, either of them may be serious if severe. Ordinary burns may be simply treated. After the pain has been relieved by plunging the burned part into cold water or bathing it with water containing common baking soda, the application of a little vaseline to exclude the air is all that is necessary.

If the clothing catches fire, however, prompt action and more careful treatment are required. Pick up anything at hand which will serve as a wrapper; a rug, blanket, shawl, or overcoat will serve. Wrap the person quickly to smother the flames, throwing him down if necessary and rolling him over and over in the wrapping material. After the flames are extinguished remove the clothing from the burned spots with great care and gentleness, cutting it and softening it with water if it adheres to the skin. Be especially careful not to break the blisters that have formed. Then anoint the burned parts with vaseline, and in all severe cases summon a physician at once.

Frostbites are generally confined to the fingers and toes, ears and nose; in other words, to those parts where the blood flow is least vigorous and where there is a large surface exposed to the cold air. The muscles may, however, be concerned as well as the skin. When a limb is frozen the water in the blood and muscles is partly turned into ice. If it is

thawed slowly, the water may resume its former relations and the body activities continue as before. But if thawed out rapidly, the water will not return to its normal condition, and inflammation, together with the final destruction of the frozen part, may follow. For this reason the treatment of frostbites or frozen parts, should be such as to cause them to thaw slowly. Rubbing frozen parts with snow or cold water is usually recommended, for this will slowly thaw them with the least danger of injury. The preservation of the frozen member depends largely upon prompt action although the thawing must be very gradual. The person should be warmly wrapped and after normal activities have been resumed, some sort of hot drink should be administered.

**Smallpox, Scarlet Fever, Measles.**—These three diseases, although distinct, are all characterized by skin eruptions. They are all contagious and all occur as epidemics, many cases appearing in a community at once. The ease with which one person takes them from another makes it necessary to isolate the patients and to quarantine the house they occupy. The cause of none of these diseases is positively known, although they are doubtless due to germs of some sort. The only methods of preventing them are by avoiding association with patients, and, in the case of small-pox, by vaccination.

*Smallpox* is the most serious of the three and, formerly produced frightful ravages. To-day it is largely controlled by vaccination. It is probably distributed by particles discharged through the skin. It is to be avoided by keeping away from persons with the disease, and by vaccination (page 386).

*Scarlet fever* and *measles* are also serious. The infectious material is certainly contained in the sputum and the discharges from the nose of the patient and perhaps in the particles given off from his skin. To avoid these diseases we must shun those sick with them, and remember that the infectious material is dangerous whether moist or dry, and that it may be carried upon toys or clothing.

## CHAPTER XVI

## THE SKELETON

We have seen how foods furnish the body with heat and act as a source of human energy in general; we may now give attention to the more permanent forms which foods take as body tissues, studying especially the skeleton and the muscles, which form the largest part of the body in bulk.

**The Functions of the Skeleton.**—The function of the skeleton is two-fold.

1. It gives firmness to the body; without such a framework, the other, softer tissues would form but a shapeless mass, with no means of bracing itself for doing work.

2. It furnishes attachments for muscles, and thus makes motions possible; muscles are so fastened to the bones as to move them, thus producing movements of the body.

All large animals, except a few living in the ocean (jellyfishes, etc.), have skeletons of one sort or another; it is the only method nature has devised for holding together large masses of soft tissues and making it possible for them to work to purposive ends. In some animals, e. g. lobsters, insects, clams, etc., the skeleton is a mere crust on the outside, and thus is called an **exoskeleton**; but the circumstances are the reverse with all "backboned" animals, including man, which are spoken of as possessing an **endoskeleton.** In the adult human, the skeleton makes up about 16% of the weight of the entire body, and comprises about two hundred separate bones; the child's skeleton contains more because during the process of growth some bones fuse together. In spite of their number, the bones are so strongly bound together by tough, stringy liaments and by muscles that the whole skeleton forms a very firm, solid unit; Fig. 120.

For convenience in study, the skeleton may be considered as consisting of two parts. (1) The **axial skeleton,** made up of the backbone, ribs and skull, forming the main axis of the body and the most rigid part of the whole; (2) the **appendicular skeleton,** or skeleton of the appendages (arms and legs). In most animals, e.g. dogs, cats and horses, both arms and legs are organs of locomotion; in birds the front appendages are modified as wings, while in man they are not organs of motion, but grasping organs (organs of prehension). In man alone the arm and hand are used for this purpose only though some of the monkeys use them for prehension as well as for locomotion.

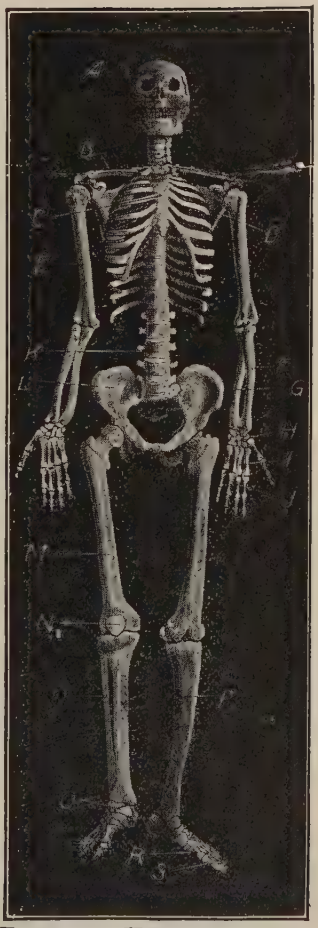


FIG. 120—HUMAN SKELETON
*A*, Frontal; *B*, Clavicle; *C*, Sternum; *D*, Scapula; *E*, Humerus; *F*, Radius; *G*, Ulna; H Carpals; *I*, Metacarpals; *J*, Phalanges; *K*, Vertebræ; *L*, Pelvis; *M*, Femur; *N*, Patella; *O*, Fibula; *P*, Tibia; *Q*, Tarsals; *R*, Metatarsals; S, Phalanges.

### AXIAL SKELETON

**Spinal Column.**—The central part of the axial skeleton is called the **backbone,** or **spinal column.** This is not a single bone but a series of **vertebræ,** irregular bones placed one on top of the other and firmly bound together; Fig. 121. Seven ring-like vertebræ in the neck are called the **cervical vertebræ;** twelve below these are nearly alike and are

termed the **dorsal vertebræ**; five heavier ones in the "small" of the back are the **lumbar vertebræ.**

Although the vertebræ differ in shape and size, each consists of a rounded portion with flat upper and lower surfaces, the **centrum,** on the sides of which arise two pieces of bone uniting to form the **neural arch;** where these two projections are joined, they are prolonged into a spine, the **neural process**; Figs. 122 and 123. When the vertebræ are placed on top of each other, with the spines pointing backward, the arches are brought over each other and the openings in the successive vertebræ, i.e. the **neural foramina,** together form a long tube just in front of the row of spines. This tube, completely surrounded by bone, contains the spinal cord, an organ of great importance and delicacy, which is thus protected from all ordinary injuries. When in position in the back they do not actually touch one another, for between each two is an elastic pad of cartilage which serves as a cushion to relieve jars. The vertebræ are connected by ligaments, running between every two vertebræ and thus tightly binding all the parts of the spinal column into a firm support. Although the backbone is as a result a strong structure, it possesses, nevertheless, a certain amount of flexibility. It has the greatest amount of strength consistent with easy bending of the body from side to side, or forwards and backwards. The verte-

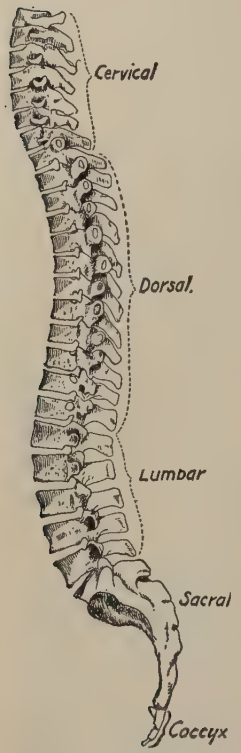



FIG. 121.—THE SPINAL COLUMN

Showing the curves and the separate vertebræ (Thompson).

bræ are so united as to form a column of bones with graceful curves (Fig. 121), an arrangement which in itself has more of the qualities of a spring than are possessed by a straight column.

In order that the legs may firmly support the heavy body, strong connection of the "hip bones" to the spine is necessary. To make this junction solid, five of the vertebræ in that region are enlarged and grown together, forming the **sacrum**; Figs. 121 and 124. Below this are four much smaller vertebræ, partially grown together and called the **coccyx**. It is the continuation of this which forms the tail in some animals.

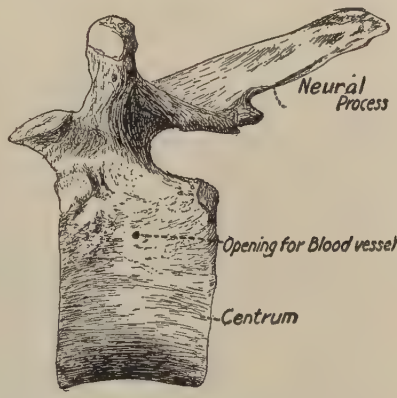



FIG. 122.—ONE OF THE DORSAL VERTEBRÆ VIEWED FROM THE SIDE

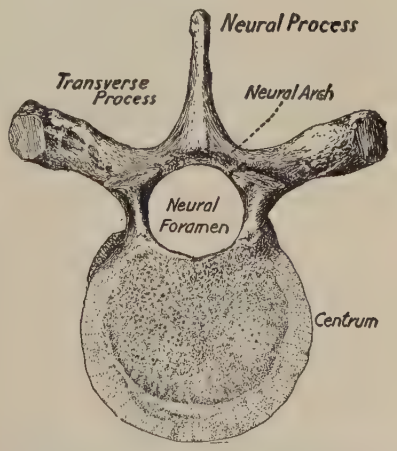



FIG. 123.—ONE OF THE DORSAL VERTEBRÆ VIEWED FROM ABOVE

**The Ribs and Sternum.**—The **ribs** are a series of slender arching bones, attached at one end to the twelve dorsal vertebræ, and bending outward and forward to enclose the thorax or chest cavity. The lower ribs afford some protection to the upper part of the abdomen also. After arching around the chest the ribs are

connected indirectly with the sternum by short pieces of cartilage; Fig. 101. This material is more flexible and elastic than bone, thus making it possible for the ribs to move freely without danger of breaking. Two of the lower ribs on each side, called **floating ribs**, are very short and are not attached to the sternum at all. The thorax, which contains the heart and lungs, is thus protected on all sides by a framework of bones.

FIG. 124.—THE SACRUM
Consisting of five fused vertebræ at the lower end of the spinal column.

The **sternum**, or "breast bone" (Fig. 120), is composed of three flat, elongate bones, placed end to end; the uppermost is roughly shield-shaped, the middle bone elongate rectangular, and the lower one triangular, with the point downward. They are so closely joined that little movement occurs between them, and the three are generally spoken of as though a single piece.

**The Skull.**—The **skull** is balanced on the spinal column and is attached to the top vertebra in such a way that it may be nodded backward and forward. The joint involved in turning the head from side to side is that between the first and second vertebræ. The skull is a complicated arrangement of bones, twenty-two in all (Fig. 125), so rigidly fitted together that there is no motion between them, except that of the jaw bone. Teeth are not a part of the skeleton, since they arise from the lining of the mouth and because this lining is essentially the same as the outer skin.

We may consider the skull as made up of three parts.

1. **The cranium,** a large, rounded box of bones firmly

united (Figs. 120 and 125) and enclosing a large cavity, is filled by the brain, the center of all mental activity. The cranium is made of eight large bones, which in the adult are dove-tailed together, the lines where they meet being called **sutures.** In childhood, while the skull is growing, they are soft and not so firmly joined, though they touch each other. If a young baby's head be examined, there will be found a soft spot in the middle where the bones have not yet come together; Fig. 126.

FIG. 125.—THE SKULL DISARTICULATED
i.e. with the bones slightly pulled apart but retaining their relative positions.

2. The **facial bones,** thirteen in number, form the face. They enclose the eyes and comprise the cheek bones and upper jaw.

3. The **mandible,** forming the lower jaw, is a single bone hinged to the temporal bone of the cranium, Fig. 125. The only movable bone in the skull, it is acted on by powerful muscles attached to each side of the cranium and is provided with a blade-like extension of its surface, so that there may be a larger area for the attachment of the muscle.

It will be noticed that the skull is especially adapted to the protection of several delicate organs of the nervous system. The brain itself is entirely inclosed in bones which are so thick that ordinary blows can not injure it. The eyes are

sunken in deep bony pits, formed by the bones in the eyebrows, nose and cheek which thus ensures them against injuries. The ears are best protected of all, since the real hearing parts are completely inclosed in hard bone inside the skull, only narrow passages connecting them with the exterior.

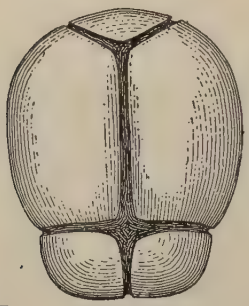


FIG. 126.—TOP OF A BABY'S SKULL

Showing the bones of the cranium not yet grown together. Upper side of figure is posterior.

### THE APPENDICULAR SKELETON

**The Shoulder and the Arm.**—Each shoulder, or **pectoral girdle,** is made of two bones. (1) The shoulder blade is an oddly shaped, triangular bone on the back of the shoulder joint. To this **scapula,** the upper bone of the arm is hinged (Fig. 127) and a shallow cavity in it forms a part of the shoulder joint. (2) The **collar bone** or **clavicle,** which is slender and in such a position as to be easily broken, extends from the sternum to the shoulder joint, thus bracing the scapula; Fig. 120.

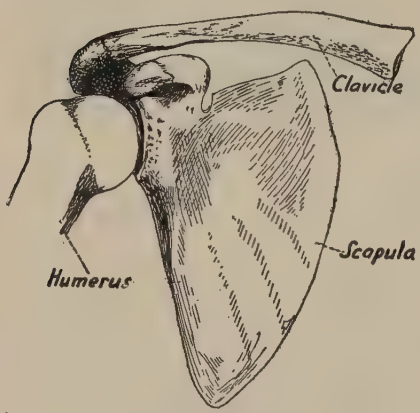



FIG. 127.—THE BONES THAT FORM THE SHOULDER JOINT

The first bone in the arm is called the **humerus** and extends from the shoulder to the elbow; Fig. 128. Between the elbow and wrist are two bones, the **radius** and **ulna,** the former on the same side as the thumb. The ulna alone

enters the elbow joint with the humerus and is large at that end. The radius, which merely touches a projection on the humerus, is large at the other end and alone makes the real joint with the small bones of the wrist, the ulna articulating with but one of these.

FIG. 128.—THE BONES OF THE ARM
The radius and ulna are shown in the position they assume when the hand is held with the palm downwards (in pronation).

In the wrist are eight very small bones, the **carpals,** between which very little movement occurs. Following these is a series of five elongate bones, the **metacarpals,** which form the framework of the body of the hand. In Figure 129 these are seen jointed to the wrist bones; also the **phalanges,** the bones of the fingers, two in the thumb and three in each finger.

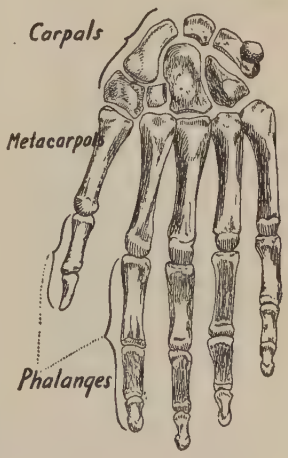



FIG. 129.—THE BONES OF THE WRIST AND HAND

**The Hip and the Leg.**—On first examination, the skeleton of the hip or pelvic girdle looks very unlike that of the shoulder girdle; Fig. 130. One very large and irregular bone is on each side; it is broad behind where it joins the sacral portion of the backbone; and at the point farthest from the midline, where the body protrudes at the hip, it presents a cavity into which fits the end of the upper bone of the leg. It curves around to the front and meets the bone

corresponding to it on the other side of the body at the midline. These bones, each called the **os innominatum,** are each made up of three bones which though separate in childhood are fused into one in the adult. Since the scapula in the young child also consists of two bones (grown together in the adult), the two girdles were originally made up of the same number of parts.

In the leg proper, one long bone, the thigh bone or **femur,** extends from the pelvis to the knee: Fig. 131. Between the knee and the ankle are two bones, the **tibia** and **fibula.** The tibia is large at each end and enters into the knee and ankle joints; but the fibula, which is smaller and on the outside, has no connection with the knee joint and little to do with the ankle. Indeed though present in the human body, the fibula is entirely lacking in some of the higher animals.

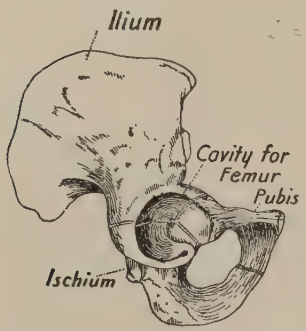



FIG. 130.—THE HIP, OR PELVIC GIRDLE
(The innominate bone) showing it to be composed of three fixed bones.

FIG. 131.—THE BONES OF THE LEG
From the thigh to ankle

The ankle is supported by seven small **tarsal bones;** Fig. 132. In early childhood there are eight of these as there are of the wrist carpals. A series of five elongated bones, the **metatarsals,** are joined to the tarsals and form the skeleton of the body of the foot. The bones of the toes are of the same number as those of the fingers and are also called **phalanges.**

## STRUCTURE OF BONE

**Shape and General Structure.**—The shape of bones is designed to render them as strong and yet as light as possible. Upon the long bones of the arms and legs comes the heaviest strain, and consequently they are the ones most frequently broken. Every bone is covered on the exterior with a thin connective tissue membrane called the **periosteum.** This is full of blood vessels and by means of the material thus brought to the bone, new matter is added to it so that this membrane plays a very important part in the growth of the skeleton.

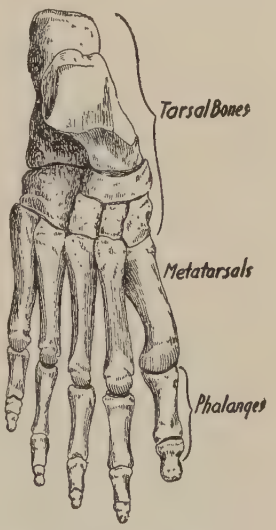



FIG. 132.—THE BONES OF THE FOOT (Thompson)

If a bone is cut open lengthwise, it will be seen to be hollow throughout most of its length, while the bone itself, especially in the middle of the shaft, is very hard and tough. This arrangement in a hollow cylinder is known to give the greatest amount of strength possible with the amount of material used. The ends of the bone which are not hollow are very much larger than the shaft, in order to furnish sufficient surface for the joint and also for the muscles, which are attached to the bone near the end. The larger the surface the more chance for the attachment of muscles and the stronger their action. If a bone at its enlarged ends were of the same dense structure as in the middle of the shaft, the whole would be very heavy; to avoid this without materially weakening it, the ends are spongy and porous.

**Marrow.**—The cavities in the middle of the long bones are

not wasted spaces but are filled with a soft yellowish-red substance called **marrow.** In addition to much fat, this material contains little bodies known as marrow cells, which, as has been pointed out, produce red blood corpuscles.

**Composition of Bone.**—Bone itself is composed of two very different substances: (1) mineral substance, chiefly phosphate of lime, which is hard and brittle, and gives rigidity; this is secreted by cells called osteoblasts, and constitutes about 35% of the entire body substance; (2) animal matter, a tougher material than lime, and neither hard nor brittle. Being partially made of organic materials, when a bone is placed in the fire the animal matter is burned away, leaving the lime only. The animal matter gives strength and toughness to the bone so that it is not easily broken; this substance is called **collagen** and makes up about 16% of a bone. Collagen is more familiar as the material which gives rise to gelatine when bones are boiled. The rest of bone material (about 50%) is chiefly water.

**Bones of Children and Adults.**—The relative amount of animal matter in the bones of children is much greater than in those of adults. Indeed, in very early childhood the bones consist wholly of animal matter and it is not until later that lime is gradually deposited in them; the bones of children can therefore be bent considerably without breaking. This is a manifest advantage, for the numerous falls and mishaps which a child suffers would produce many disastrous results were the bones as brittle as in later life. But for this very reason it is necessary that the child be taught habits of holding the body erect and in proper position. If the body is habitually allowed to stoop, or assume a position which keeps the bones bent out of their proper form, they will be almost certain to retain this shape when the lime is deposited in them and they become hardened. A good straight form with erect shoulders adds much, not only to a person's appearance but also to his health and consequent happiness in life.

Any kind of dress which presses upon the bones is sure to result in deformity. If one wishes health, he should let his body grow as nature intended and not curb it by confining it in tight garments. If the boy or girl stands erect and is not hampered by constricting clothing, the bones will develop properly. The deformity of bowed legs, however, is not due, as frequently supposed, to the fact that a child has been allowed to walk too early. "Bow legs" are found chiefly among poor children, and are caused by a disease called *rickets*, brought on by improper food and lack of air and sunlight.

Since so much in the way of body strength and usefulness depends on the perfect condition of the skeleton, it is simply a matter of common sense that care should be taken, especially with growing children, that the diet contain all materials necessary for bone making. Milk and its products, with wheat and oat cereals, are valuable in this connection.

**Repair of Broken Bones.**—The animal matter in a bone is the only part of it which is alive, and it is this, therefore, which effects its growth and repair. Each bone is provided with tiny blood vessels which enter through small openings and then branch into numerous vessels, running in every direction inside the bone and furnishing the living parts with materials for all necessary repairs. The bone is filled with myriads of minute living cell bodies, called **bone cells,** which have the power of making new bone material when necessary, and thus of repairing broken bones. If a bone in the body is broken and the ends are brought together, these living cells begin at once to unite the two ends, and if allowed to continue this work undisturbed for a few weeks, will completely join them, making the bone as strong as ever.

The value of the periosteum, too, in this matter of bone repair is very great, for, being filled with blood capillaries it can furnish new material. It has even been shown that the periosteum, if not disturbed when a bone is taken out of the body, can replace all the hard parts of the bone.

During a period when a bone is being repaired it must be kept perfectly quiet, for any movement would easily tear apart the newly made materials. Consequently, the surgeon always binds broken bones in such a way as to prevent motion of the parts until they are well knit together. The *setting of a bone* by a surgeon consists simply in bringing the two broken ends nicely together and then binding them in proper position. Since the animal matter in the bones of children is so much more abundant than it is in adults, it follows that broken bones are more easily mended in childhood than in later life. In more advanced years when the amount of animal matter is further decreased, the bones grow more brittle and are more easily broken. At the same time they are not so easily repaired, because of the scarcity of living bone cells.

**Microscopic Structure of Bone Tissue.**—Figure 133 shows a very thin piece of bone highly magnified.[1] It consists of

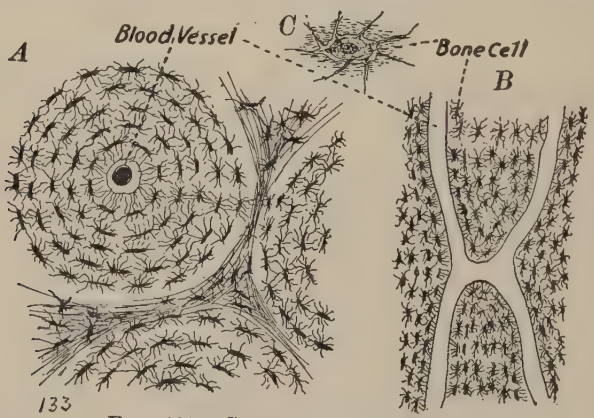



FIG. 133.—SECTIONS THROUGH BONE

*A*, cross section; *B*, longitudinal section. Canaliculi are the minute canals radiating from the elongate, black areas (lacunæ). Lamellæ are not shown.

groups of concentric rings, arranged around small openings. These openings indicate the places where canals, running

lengthwise of the bone, and containing blood vessels have been cut off; the concentric layers of bone tissue about these are called bone **lamellæ.** In the living bone these central openings are occupied by blood vessels. Arranged in rings around the vessels between the scale-like layers of the lamellæ, are a large number of small, lens-shaped spaces, called **lacunæ,** each of which shows numerous fine lines radiating from it. Row after row of these little spaces appear arranged around the central blood vessel, forming larger and larger rings until they reach similar rings belonging to other centers.

Each of the little spaces in the live bone is filled with living matter, which is the remainder of what was originally a bone cell. Because of the deposit of such mineral matter about it, the original shape of the cell has become almost unrecognizable. The radiating lines are really minute tubes, **canaliculi,** passing from one row of spaces to the next. Since each row is connected with the next, and since the inner row, by means of the little tubes, is connected with the central space and hence with the blood vessel, even the outer row of spaces is supplied with nourishment derived from this vessel. It is because the bone possesses so many living cells, so well supplied with nourishment, that it can be so easily repaired.

## CARTILAGE

We have noticed that the ribs are not united directly to the sternum, but that there is a short piece of softer material at their front ends; this material is **cartilage,** a substance which forms an important part of the skeleton. Early in life most of the bones are made of cartilage. Even in the adult some cartilage still remains; e. g. the cushions between the vertebræ, the supporting pieces around the windpipe (Fig. 98), the pieces at the ends of the ribs (Fig. 101), in the joints, and in the outer ear, which consists of cartilage covered with skin. Cartilage, which is flexible but very tough, is

much softer than bone and can be readily cut with a knife. It differs from bone in that it is not supplied with blood vessels. Under the microscope a thin piece of cartilage appears as in Figure 4, page 14. The cells composing it are far apart, separated by much intercellular substance.

When, in early life, certain cartilage masses begin to turn into bone, the change does not take place throughout the cartilage uniformly, but at certain points only, called **centres of ossification.**

Cartilage is not so readily repaired as bone, but on the other hand, it is not so easily broken. A broken rib is quickly mended in a few weeks and is as good as ever, but if the injury breaks or tears the cartilage, its mending may take a long time.

## JOINTS

When two bones are fitted together in such a way that there is no movement between them, as for example, the bones of the cranium, the line of joining is generally called a **suture joint;** where movement is possible, a **joint** is said to occur. Of the true joints there are two kinds, imperfect and perfect.

**Imperfect joints** are those in which the bones concerned do not actually glide over one another although a certain amount of movement is possible because of the flexibility of the elastic cartilage between them. Such joints are noticed where the front ends of the ribs approach the sternum; movement takes place at every breath, though it involves only bending the cartilages which occur there. The bending and slight torsion which may take place between any two vertebræ also illustrate the action of imperfect joints. **Perfect** or **movable joints** are the sort generally thought of as joints and occur where the end of one bone actually turns on some part of the surface of another.

As will be pointed out later (page 275), the muscles which produce bending are not necessarily located near the joint they operate; such an arrangement would often result in a difficult and bungling sort of movement.

Since accidents at movable joints are always likely to be serious because they are apt to cause stiffness, we shall examine one or two carefully in order to learn their mechanism. Perfect joints are of several different kinds, but most of them are modifications of three simple types: the hinge joint, the ball-and-socket joint and the pivot joint.

**The Hinge Joint.**—In the *hinge joint* the bones are able to move back and forth in one direction only, like a door on hinges: the knee, the elbow and the joints of the fingers are good examples. Since all hinge joints are very much alike in structure, the description of one will show the salient features of all.

*The knee joint* is made up of the femur and the tibia bones; Fig. 131. The lower end of the femur is large and rounded in one direction at the end, while the upper end of the tibia is slightly hollowed on top; when the bones are placed together, their shape permits movement only in one direction. The rounded ends of both bones are covered with a thin layer of cartilage, making movement easier. Two separate ring-like cartilages, the **semi-lunar fibro-cartilages,** one on the outside and one on the inside of the leg, furnish extra padding to relieve the body of jars, and also fill up the spaces, making the joint more compact. In the living joint, there is wrapped around the ends of the bones the **synovial membrane,** which secretes into the joint a liquid, the **synovial fluid,** the purpose of which is to moisten the surfaces and prevent friction. The free motion of the joint is dependent upon the presence of this fluid and if for any reason the membrane ceases to secrete it, friction develops, motion becomes difficult, inflammation sets in, and eventually the bones are likely to grow together and the joint to become stiff. All of the parts are evidently

designed to make the movements of the bones upon each other smooth and free, with the least possible friction.

The bones are bound together by tough bands called **ligaments.** At the knee joints there are several (Fig. 134); there is a pair of short ones, the **crucial ligaments,** running directly between the ends of the bones and crossing each other like the parts of a letter X. More important are those outside of the joint and extending over it from one bone to the other. On either side there is a **lateral ligament,** attached to the femur and extending down to the sides of the upper parts of the tibia and fibula. Another, the **posterior ligament,** at the back of the joint, is attached to the same bones. The **anterior ligament** (in front) is different from the others in having in the middle, a rounded, flat disc of bone, called the knee cap, or **patella,** strengthening the joint and protecting the more delicate parts within from injury. There is another, rather irregular ligament, called the **capsular ligament,** larger than the others and partly covering them all, like a sac wrapped around the bones and fastened to the lower end of the femur and the upper end of the tibia.

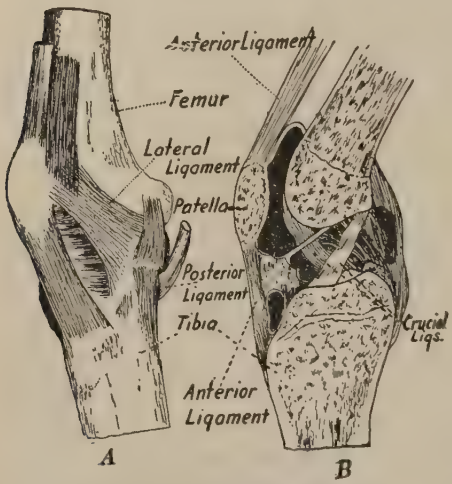



FIG. 134.—THE KNEE JOINT

*A* shows the exterior ligaments. *B* shows the joint with the external parts removed. (Thompson)

The other hinge joints in the body differ from that at the knee only in slight details. The exact position and number

of ligaments vary in them, and no other joint has a bone in its ligaments like the knee cap. But they all have the same smooth, rounded surfaces, the synovial membranes and fluids, the ligaments and muscles to complete the joint, and are all, of course, bound together on the outside by the skin.

**Ball-and-Socket Joints.**—There are only two typical examples of ball-and-socket joints, one at the shoulder and the other at the hip. As the name indicates, one bone in such a joint ends in a rounded, ball-like head, while the other presents a concave socket into which the ball fits. In an arrangement of this kind the motions of the bones are not confined to one direction, giving greater freedom of motion, but less strength, than the hinge joint.

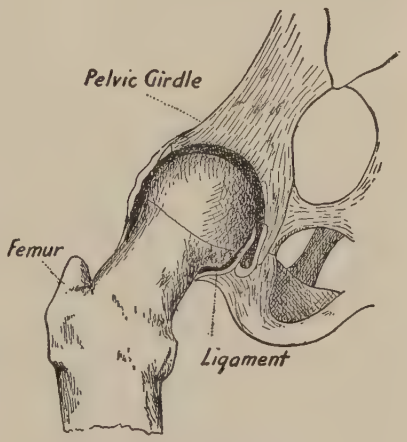



FIG. 135.—THE HIP JOINT

Three bones enter into the shoulder joint, though only two of them are of much importance. The humerus, the upper bone of the arm, has at its upper end a good sized, rounded head fitting into a socket made by a concave part of the scapula; Fig. 127 This cavity is very shallow but in the living body there is a little rim of cartilage around its edge, making the socket deeper, and the joint, therefore, somewhat more secure.

It will be noticed from the figure that two little projections of the scapula hang over this socket; while these do not form a part of the socket proper, they protect it from injury above and in front. It is evident that when the arm bone is lifted,

it will soon hit these projections, and its movement in that direction will consequently be stopped. The round ends of the bones are rendered smoother by being covered with cartilage, as in the hinge joint, and a membrane around the joint secretes a synovial fluid for moistening the joint and reducing friction. The bones at the shoulder joint are bound together by ligaments, but these are not so numerous as at the knee joint. The only important one, the capsular ligament, is attached to the scapula around the socket, and then extends out over the head of the humerus in such a way that it has a wide, extended fastening to that bone. It is so loose as to make it possible for the bone to move in any direction without hindrance. If it is cut the bones come apart at once.

The ball-and-socket joint at the hip differs from that at the shoulder, in that the muscles are much more massive and powerful and the socket is much deeper. The joint is thus firmer but has less freedom of movement; Fig. 135.

**Pivot Joints.**—In the case of a pivot joint, the two bones concerned rotate on one another. In the movements of the head, for example, all forward and backward tilting occurs between the occipital bone of the skull, and the first, or **atlas,** vertebra, the joint there being essentially a hinge joint. All turning from right to left (not tilting from side to side) occurs between the first, **atlas**, and second, or **axis** vertebra, one bone rotating on top of the other and thus forming a pivot joint. The turning of the radius bone of the lower arm on the end of the humerus bone of the upper arm is another good example of a pivot joint; Fig. 128.

## INJURIES TO JOINTS

There are two kinds of accidents, not counting broken bones, which occur, and frequently occur together, in joints. These are **sprains** and **dislocations.**

**Sprains.**—A sprain is due to the stretching of some of the

ligaments in the joint to such an extent that they are more or less torn, a condition followed by considerable pain and inflammation, accompanied by swelling. The injury may be only a slight strain or it may be a severe rupture of the ligaments, more serious than a broken bone, requiring longer to heal, and being more likely to result in permanent injury. The best treatment is to place the joint in the most comfortable position and then apply, first, *hot water* (as hot as endurable), then, *cold water*. The joint should then be tightly bound in bandages. It is well to *rest* the joint, but the impression that it should not be used until it is healed is a mistaken one, for this is likely to increase stiffness and make the joint useless for a very long time. Indeed, a sprain heals more quickly if the joint has some exercise, and after a day or so, when the first inflammation has subsided, it should be exercised frequently, and used as soon as possible. This treatment is a little painful, but it results in making the joint usable much sooner than the old method of completely resting the joint until the sprain is healed.

**Dislocations.**—A dislocation occurs when the bones in a joint are pulled out of position, as, for example, when the humerus is pulled out of the socket at the shoulder, or the end of the femur is pulled out of the depression in the tibia, in which it naturally rests. The first thing to be done is to pull the bones back into position. This usually requires the skill of a surgeon, unless the dislocation should occur in one of the small joints of the finger, which is easily put back into its proper place. Since a dislocation is almost sure to be accompanied by a strain and rupture of the ligaments, it should, after the bones are put back into position, be treated just like a sprain.

### THE CARE OF THE FEET

That the feet may be a source of great discomfort many people are aware; but that health is closely connected with the condition of the feet is not so generally recognized. To

preserve one's health, exercise is necessary; no one can maintain his body in good condition for many years without it. It is difficult to think of any real exercise in which the feet do not take some part. Walking, which is about the mildest form of exercise, is of course absolutely dependent on the condition of the feet. If they are uncomfortable when one stands or walks he will stay at home as much as possible, or will use conveyances instead of his own muscles. He will become more and more indisposed to exercise and out-door life generally, and his health will inevitably suffer. As much attention should therefore be paid to foot wear as to clothing for other parts of the body, and there is no reason why one should not retain through life feet which will be a comfort, instead of a painful hindrance and an agent limiting him in all his physical activities.

Climate and modern customs compel us to wear shoes, but the barefooted child of summer time is still the one who experiences the greatest comfort, and whose feet teach us what we all need to know as to the shape of shoes. Fashion, rather than health or comfort, has dictated the shapes of our shoes, and there are few people who do not suffer in consequence. Practically all defective feet, save those improperly shaped from birth, are due to badly patterned footwear.

FIG. 136.—THE BONES AND LIGAMENTS OF THE FOOT
To show the arch of the instep. (Modified from Thompson)

All common troubles of the feet have to do either (1) with the skin, or (2) with the bones and ligaments in the foot skeleton. The most common skin deformities causing pain are corns and bunions. Even though the shoe is properly shaped, if it fits too loosely or too tightly, corns are the al-

most inevitable result. If the shoe is too tight, a slight amount of rubbing will irritate the skin and provoke the growth of corns; if the foot moves inside the shoe at each step, it of course rubs on the leather, and in nature's effort to counteract this, a callous spot is formed which grows constantly thicker. Tight and badly shaped shoes have a still more unfortunate effect on the small bones of the toes and ankle, forcing these into unnatural, strained positions. To appreciate this, the free, unconfined foot should first be studied. Between the heel and the ball (Fig. 136), the foot does not touch the ground, save along its outer border and there only slightly. Moreover, on the ball of the foot the weight falls largely on the sides, i. e. just back of the grea and little toes. There is, thus, one longitudinal and one transverse arch in the foot. These act as springs: when one steps, the weight of the body is first thrown on the long arch (on the one between the heel and the ball); as one rises on the toes in going forward, the weight is transferred to the transverse arch; and as it flattens, the foot should be able to spread a little, and all the toes, each separately, to take an active part in pushing the load ahead.

It is thus very easy to see what high heeled shoes mean to the long arch; they mean that the weight will be thrown forward onto the ball, the ligaments at *A* (Fig. 136) will be strained, and all the bones in the ankle will be forced into unnatural positions with consequent strain on those ligaments. In connection with the long arch it should also be noticed that if one "toes out" excessively in walking, the weight, as one leans forward, is thrown on the inner side of the long arch, which has no support at all, save that of the muscles and ligaments. The weakening of the ligaments or muscles concerned in the long arch, whether through badly shaped or high heeled shoes, faulty position of the feet, or lack of exercise, leads to a very painful condition called **flat-foot**, in which the arch partially gives way, letting the

foot down flat on the ground and causing the nerves and muscles to suffer much under unnatural strains.

To avoid the misfortune of a flat foot one needs to acquire the habit of "toeing in" slightly. If a person practices rising on the toes a few times each day, and in thus rising throws the weight first on the little toes and then on the great toes, and also learns a method of walking—like the Indians—with toes pointed straight forward or a little inwards, he will generally avoid "flat foot" and broken arches. This method of walking is best acquired by throwing the hips slightly forward with each step.

Narrow-toed shoes affect the transverse arch in front. If the toes forming this arch are crowded and confined, there is nothing for them to do but to press mechanically upon one another or be displaced; and when the weight is thrown forward on the toes, if these cannot spread, they bind or are forced to cross one another.

A tight shoe incidentally interferes with circulation in the foot, which, of course, means the inadequate nourishing of all the tissues concerned, and in winter especially makes cold feet inevitable. Discomfort in any part of the body signifies that there is nervous irritation there, and waste of nerve energy in any one organ means that less will be available for the rest of the body.

A healthful shoe should, therefore, have low heels, should conform to the shape of the foot, should not be so tight as to pinch, should be made of yielding upper leather so that the toes may be moved, and should fit in such a way that the " breaking in " of the shoe will not be a necessary and dreaded experience. Common sense and public sentiment are demanding that such shoes be manufactured more and more extensively nowadays, and they can be obtained if one will insist upon comfort and health, instead of fashion and false notions of elegance.

## CHAPTER XVII

### MUSCLES

While the skeleton is the hardest part of the body, it is not the most abundant tissue and does not require so large a part of the food materials for its building or maintenance as do the muscles. The skeleton gives the body its general shape, but the bones are of use only because of the muscles attached to them. Life, of course, could not continue if we lacked the ability to move, and even though the internal organs of breathing and circulation are in good condition, there is no more pitiful sight than that of a person whose limbs are withered or whose muscles are paralyzed.

Muscles make up the heaviest part of the arms and legs, of the shoulders and hips. They occur in the trunk of the body, both in front and behind. The heart, arteries and veins are chiefly composed of muscle tissue; the tongue, œsophagus, stomach and intestine are also largely muscular. In short, about 44% of the whole body is made of muscle cells, and most of the food taken into the body is used in building them up, and in furnishing them materials on which they constantly draw while doing work.

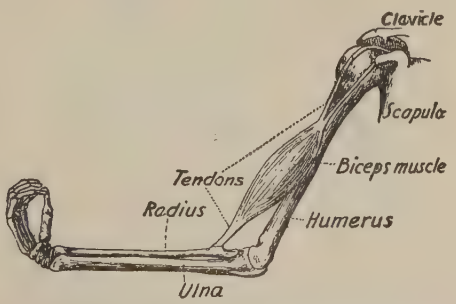



FIG. 137.—THE ARM (SEMI-DIAGRAMMATIC) Showing the relations of the biceps muscle. From the figure it is evident that if the muscle contracts slightly the fore arm will be lifted over a great distance.

Although muscle is usually thought of merely as muscle, there are three different kinds: **striped, smooth** or **unstriped,** and **cardiac.** This division is made both on the basis of their microscopic structure and of their mode of action.

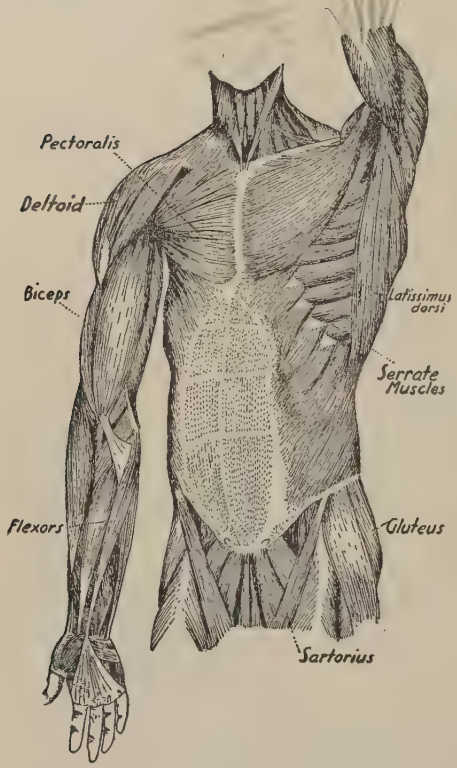



FIG. 138.—THE CHIEF SUPERFICIAL MUSCLES ON THE UPPER PART OF THE BODY (Thompson)

## STRUCTURE OF STRIPED MUSCLE

Striped muscles include all those over which we have control, and which are attached to bones. A good example for study is the biceps muscle in the upper arm.

The biceps muscle is shown in its natural position in Figure 137. It is a long mass of flesh, large and reddish in the middle, and tapering at the two ends into a dense, whitish band, called a **tendon.** The middle portion, the muscle proper, is alone capable of contraction; the tendon simply fastens the muscle to the bone.

A tendon is made of the same material as that of which ligaments are composed; *ligaments unite bones to bones, and tendons unite muscles to bones.* No muscle is united directly

to a bone; there is always a tendinous tissue between them, although it may not be noticeable. On the other hand the tendon may be very long; for example, some of the muscles which move the fingers are near the elbow; Fig. 138. The advantage of this is obvious; for if the muscles were located in the parts used, these would be unwieldy and large. Imagine the size and awkwardness of the fingers for example, if all the muscles concerned in their work were located immediately in them. The muscles which operate a bird's leg and toes are placed high up on the leg among the feathers. The leg of a wading bird, like the flamingo, is a striking example of this contrivance for obviating cumbersome mechanism and allowing freedom of movement. The tendons are popularly called cords. The wrist is little more than a bundle of such cords around the bones.

As Figure 137 shows, the upper part of the biceps muscle is attached at the shoulder by two tendons (whence the name biceps), while the lower end is fastened by a tendon to the radius bone below the elbow joint but not far from it. A slight shortening of the biceps will, therefore, lift the arm through considerable distance.

**Microscopic Structure of Striped Muscle.**—If a muscle be cut across, it will be found to consist of small parts, called **fasciculi,** closely bound together, and giving a " grain " to the muscle like that in a piece of raw steak. If one of these fasciculi be pulled to pieces and examined with a microscope, it will be found to consist of a large number of minute threads, or fibres; Fig. 139.

These **muscle fibres,** which are too small to be seen with the naked eye, always run lengthwise but do not usually extend the whole length of a muscle. These fibres are cylindrical bodies, traversed by fine cross lines, or **striæ,** which gives rise to the name " striped muscle." Each fibre consists of an outer tube, the **sarcolemma,** and a jelly-like substance within. It is this soft material in the tube which is the

active part of the muscle, the sarcolemma itself having nothing to do with its movement. A muscle, therefore, consists of thousands of minute fibres, each able to contract, bound together in bundles to form fasciculi.

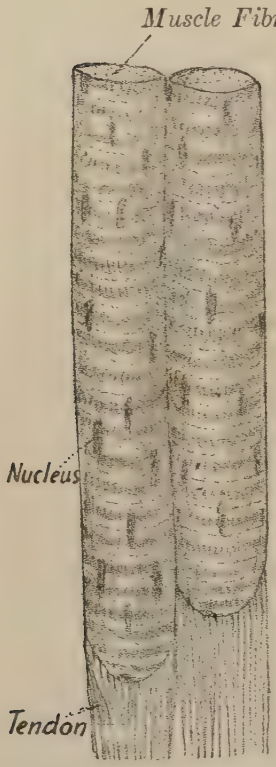



FIG. 139.—TWO MUSCLE FIBRES With tendon fibres attached at their ends.

Tendons, ligaments, sarcolemma, periosteum — all belong to the body material called **connective tissue.** It is always fibrous or membranous in structure, and is so abundant that it has been said that if all other tissues were dissolved away, the shape of the body would still be perfectly preserved.

**Blood Supply to Muscle.**—Into each muscle enter one or more arteries which divide into minute branches and finally end in a set of capillaries (described in a previous chapter; Fig. 80). In this way each individual muscle fibre is in contact with blood vessels and from them obtains its nourishment—necessitated by the activity of the muscles. If a muscle is soaked in water for a while, the blood will filter out and leave the muscle nearly white.

**Contraction of Striped Muscle.**—When a muscle contracts the two ends are simply drawn toward one another, while a corresponding swelling occurs at the middle of the fibre. The muscle does not really become any smaller, but merely shorter and larger around; Fig. 140. It is evident from Figure 137 that

the shortening of the muscle will lift the arm. After the arm has been thus lifted, the muscle may remain contracted for a time and the arm held up, but it requires a constant effort to keep the muscle contracted, and just as soon as the effort ceases, the arm falls of its own weight. The muscle has no power of forcibly lengthening and pushing the arm down, but as the arm falls, it pulls out the muscle to its elongated form again. On the back of the arm is another muscle which acts in opposition to the biceps, these two muscles thus forming a pair, each of which produces an action opposed to that of the other. They cannot both act at once.

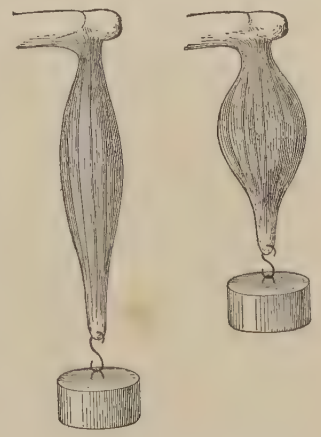


FIG. 140.—DIAGRAM
Showing that the muscle shortens though it does not change its bulk when it contracts.

**Nerve Control of Voluntary Muscle Action.**—While there are some muscles in the body (the heart, for example) which perform very regular, apparently spontaneous contractions, all the body muscles are more or less under the influence of nerves, and the striped muscles act only when stimulated by the brain or spinal cord. It is because they are under the control of the will that they are called **voluntary muscles.** If a single muscle contracts, it produces motion of a single bone in a single direction. The motions of the body are, however, rarely simple, but generally very complicated. In the process of walking nearly a hundred muscles are first contracted and then relaxed in regular order. In throwing a baseball, nearly all of the three hundred muscles of the body are brought into use to some extent, and the remarkable thing is

that each muscle must be contracted to just the right amount at just the right moment, or the ball will go wide of the mark. To insure the harmonious action of all these muscles so that the ball will go exactly where it is intended, requires a most wonderful control. One does not, of course, have any consciousness that he is regulating all these muscles. He simply decides to throw the ball, but the brain unconsciously so regulates the stimuli sent to the muscles that they act in the order to produce the desired result. "Practice makes perfect," simply because the brain has had the opportunity of learning to exercise this wonderful control over the actions of the numerous muscles.

**Tetanus of Striped Muscles.** —The term **tetanus,** although not so familiar, has much the same meaning as the word "cramps." When one keeps a muscle contracted as, for instance, when he holds a weight at arm's length, he does this by sending stimuli into the muscles very rapidly, ten to twenty per second—so rapidly that the muscle does not have time to relax between the successive stimuli. As long as these stimuli continue, the muscle remains contracted, i.e. in a condition of tetanus. All of our muscle actions are really of this character. Sometimes, when a muscle is tired and perhaps quickly cooled by plunging into cold water, it is thrown into a similar state of contraction or tetanus without one's willing it or being able to stop the contraction. We then call it " cramps," but it does not differ from ordinary tetanus, except that it is not voluntary.

**Effects of Heat and Cold on Muscle Action.**—A jockey drives his horse a couple of miles or so before putting him into the race " to get him warmed up," and athletes for the same reason take some gentle exercise before undertaking the actual contest.

Whether the benefit of these preliminary exercises is really due to the warming of the muscles or to an increased

circulation may be open to question, but there is no doubt that muscles function best when warm. Experiments with cold blooded animals, like the frog, show that their muscles will contract and relax five times as rapidly when warm as when cold. When cooled to 40° F., they will not contract at all, a condition known as **cold rigor.** On the other hand, if raised to a temperature much above 104° F., they become stiff and will not contract, a condition called **heat rigor.** The effect of heat upon the muscles of warm blooded animals is essentially the same. The numbness of the human muscles when chilled excessively is an illustration of the effect of cold which has come within the experience of almost everyone. The muscles of warm blooded animals can contract at a somewhat higher temperature than can those of the cold blooded variety, and it does not take so low a temperature to stop their action.

**Fatigue of Striped Muscles.**—When one is tired and it becomes more and more of an effort to make the muscles of the body contract and accomplish tasks, it is not primarily due to the fatigue of the muscles themselves but to that of the nerves. The muscle itself, however, on account of changes which take place in it after doing a large amount of work may become fatigued. The factors which enter into the phenomena of fatigue are not all thoroughly understood, but a common supposition that weariness in muscles is relieved by merely feeding them, by stopping for a meal, for instance, is certainly erroneous. Not only is the food not at the disposal of the muscle for a period of several hours after it is eaten, but it has been proved that a muscle can recover to a considerable extent from fatigue, even when no blood at all is flowing through it.

**Main Voluntary Muscles in the Body.**—Figure 138 shows the distribution of some of the principal muscles on the exterior of the body. There are more than three hundred voluntary muscles, some large, some small, some short and some long. They are commonly enlarged in the middle and

fastened by tendons at the ends and generally extend between two bones, moving one upon the other when they contract. The muscles are generally arranged in pairs, one muscle of the pair acting in opposition to the other. This is necessitated by the fact that muscles cannot push the bones, their sole power being that of contraction.

Muscles are usually so attached to bones that a short contraction of the muscle will produce a much larger movement of the bone. For example, it has been seen (Fig. 137) that the biceps, by shortening an inch, will lift the hand several inches. This gives great freedom and quickness of motion. A few muscles, however, are fastened in such a way that the muscle contracts through a greater distance than that through which the weight is moved; this gives greater strength, but less movement. An example of this type of arrangement is seen in the "calf" muscle of the leg, when one rises on the toes; Fig. 2.

### STRUCTURE OF UNSTRIPED MUSCLE

Unstriped muscles include all those in the walls of the œsophagus, stomach and intestine, those in the arteries and veins and in the contractile parts of the kidneys, ureters and bladder. Unstriped or plain muscles are not attached to bones and are always found in the walls of hollow organs. Although, like striped muscles, they appear to act only when stimulated by the nerves, they cannot be controlled through the will and are, therefore, called **involuntary muscles.** Since they are unattached and in sheets, e. g. those surrounding or running lengthwise of the œsophagus, they have no tendons.

Plain muscle is composed of very small cells or fibres each with a single nucleus; Fig. 8, page 16. One of the greatest differences between plain and striped muscles is in their modes of contraction. Smooth, or plain muscles contract very slowly, several seconds often being required for a single contraction, and they may remain contracted for some time. Voluntary muscles, on the other hand, act very quickly both

when contracting and when relaxing. Because involuntary muscles act so slowly they are very easily thrown into a condition of tetanus. Indeed, so slow is their response to stimuli that in some forms of smooth muscle, one stimulus in five seconds is sufficient to prevent the muscle from relaxing at all.

It is a great gain to us that so many muscles as are present in the entire digestive, blood, and excretory systems can perform their daily and nightly work without any thought or bidding on our part, and without error in time or rate.

Curiously, however, smooth muscle has a disposition to act with apparent spontaneity. If a bit of the circular muscle of the intestine of some animal be cut out, hung up by one end and stretched by a light weight attached to the other, it will very soon lift the weight and then relax again. The muscle makes these movements over and over again without any stimulus and they continue until the muscle is exhausted or until its unusual exposure results in its death.

Isolated from the body in this way, the muscle can plainly receive no stimulus from the brain, and, although different kinds of smooth muscle act very differently in this respect, they all have this power of spontaneous movement when entirely disconnected from the central nervous system. Whether or not there resides among the muscle cells some nerve influence which is the exciting agent is still an open question.

Although in many respects striped and unstriped muscles act differently, yet in others their relations are the same. Both seem to require the stimulus of nerves to make them contract although in one case the contraction is voluntary and in the other involuntary. Both can be thrown into tetanus by repeated stimuli. Both are affected by heat and cold in the same way. Both become fatigued from long action.

### CARDIAC MUSCLE

The muscles of the heart are unlike any others, although in structure as well as in action they have some points of simi-

larity with striped and unstriped muscles. The cells composing them are an elongate rectangular in form, and the fibres made up of these cells show irregular striping; Fig. 141.

In its action cardiac muscle is unique in several ways; it acts quickly, though not as rapidly as the ordinary striped variety. Unlike either striped or unstriped muscle, it always contracts to its shortest possible length, no matter how weak the stimulus applied to it. It can "beat" when unconnected with the brain, but even then it apparently depends for its impulse upon nerve cells in its own tissue.

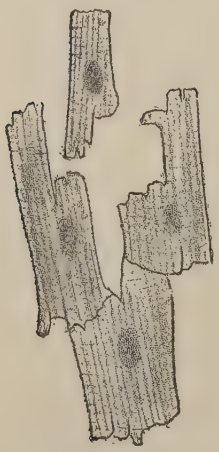


FIG. 141.—CARDIAC MUSCLE CELLS

Cardiac tissue is unique in that it cannot be thrown into tetanus. As has already been noted, this condition is usually provoked by the rapid recurrence of some stimulus. In heart muscle, however, two succeeding stimuli do not produce any larger contraction than one, and if another is applied just before the muscle begins to relax, it has no effect. As soon as the muscle really begins to relax, it becomes open to stimulation and if irritated will begin a second contraction before it has fully relaxed from the first. Hence, no number of repeated stimuli can induce tetanus in cardiac muscle; it must begin to relax before it becomes responsive to any outside influence.

## USE OF MUSCLES

**Effect of Use.**—It is a fact almost too trite for mention that the activities of both work and play tend to strengthen the body. But increased strength is only one of the benefits derived from the use of the muscles. When muscles are active, all the other organs of the body are affected, and

while the size of the muscles is generally noted as proof of the beneficial effect of exercise, perhaps greater stress should be laid on the toning up of all the internal organs, which results when they have been supplying the active muscles with energy and clearing away the débris resulting from "wear and tear."

Unlike inorganic substance, muscle increases instead of diminishing in size with use. This is true of other living matter also, e. g. brains, which grow with exercise. No one can explain this characteristic of muscle fibre, though it is inherent in the nature of the substance.

**Effect of Disuse.**—The result of failure to use muscles is just the reverse of the effect of use, i. e. they grow smaller and weaker, and less perfect control of them is possible. Some of the peoples of India believe it a religious duty to hold their arms still and have continued to hold them so until they have become stiff and useless, the muscles losing absolutely all power of contraction. Although in civilized countries, one rarely sees such complete loss, a partial loss of power is common among all classes of people. Children in their play are pretty sure to use all their muscles and are likely to develop them uniformly, but an adult is rarely as capable of free action as a child. As one grows older and becomes quieter, some of the muscles always suffer from disuse. If he uses trolleys and elevators, the leg muscles suffer, and the adult may lose the power to walk as far as the child. The right hand is used so exclusively that the muscles of the left become weak. The habit of sitting in comfortable reclining chairs gives the back muscles too little exercise and they often become so weak that it is really difficult for one to sit upright for a very long time without some sort of support. Some people use the laughing muscles so seldom that at last they can scarcely be brought into action. Examples are numerous, for few persons use their muscles in such a way as to produce uniform development. Every one should re-

member that *each muscle he fails to use will become weak and degenerate.*

**Need of Exercise.**—The great value, indeed the necessity, of exercising the muscles in order to retain good health is, therefore, evident. It is hardly necessary to advise the average school boy or girl to take exercise, for the plays of childhood usually furnish plenty of it. But when the boy or girl outgrows childish habits, and becomes a serious student, or goes to work at some routine employment, there is always the danger of poor bodily development. The time between childhood and maturity is the period when sufficient exercise is especially necessary to force all the muscles into proper, harmonious growth. When a person has out-of-door work to do, or indeed any work which requires considerable muscular activity, he does not need to think of exercise. But in modern city life, young people have comparatively little opportunity for muscular exercise and are almost sure to suffer from the lack of it unless particular attention is given to the matter. It is for this very reason that gymnasiums have been established in schools and elsewhere, and they should be patronized by every person whose business is not such as naturally to involve exercise.

Exercise should not be violent. It is of no advantage to try to lift heavy weights, or to do difficult feats in the gymnasium. Indeed, such exercise is liable to injure young people. We have noticed that the bones of children are not all knitted together, and the severe strains from attempting difficult exercise and lifting heavy weights are apt to do permanent injury to the incompletely fused bones. Athletic contests are certainly useful, but the tendency nowadays toward excessive exercise in one line rather than the general use of all muscles results too often in unreasonably overtaxing one's strength. Though the results of the straining may not be evident until long after its occurrence, when they do appear in later life, the person finds himself a per-

manent invalid. Exercise is useful and necessary, but athletics are frequently harmful in their effect on the body.

**Exercise for the Student.**—The person who usually needs the most emphatic advice as to exercise is the one who is ambitious to become a scholar. He much prefers to remain at his books, though he above all others should be the one to take regular recreation. He who studies all the time is in the end outstripped, even at his studies, by the one who plays as well as studies. No one can become a scholar who neglects to develop his body while cultivating his brain. He will be likely to find in a few years that he must give up study altogether because his body has been allowed to become weak while carrying out the dictates of his brain. Colleges have been forced to make gymnasium practice a part of the student's regular work in order to counteract his tendency to shut himself up with his books.

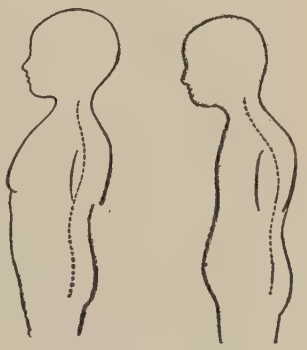


FIG. 142.—DIAGRAM

Showing the effect upon the poise of the body produced by improper standing posture. The dotted line represents the backbone.

**Kind of Exercise.**—Exercise is always most beneficial if it is pleasant; exercise merely for the sake of using muscles is sure to become irksome. Hence, games of base-ball or tennis, rowing or bicycling in the country are preferable to gymnastics or hard work at a required occupation. The mind needs its recreation, as well as the body its exercise. Out-of-door games are best. Bicycling is an excellent exercise, although attempts to take long rides are mischievous, and the habit of stooping over the handle bars and "scorching" is extremely bad. Horse-back riding and walking are also good, but walking for exercise should be varied by some running or rapid walking up hill, so as to make one somewhat

breathless, for the lungs need exercise as well as the muscles, and a quiet walk does not give them as much as they need. The amount of exercise should be equivalent to at least a three-mile walk each day. When it is possible, one should not take it till two or three hours after eating.

FIG. 143.—DIAGRAM
Proper and improper sitting postures.

Everyone admires a person with an erect carriage and a good form. This always means grace and easy motion, and it also means good health. A good figure is more dependent upon the continued use of the muscles of the whole body than upon the actual shape of the body. It is the constant exercise that they are required to take that gives the West Point cadets their splendid bearing.

FIG. 144.—DIAGRAM
Showing the curvature produced by carrying a parcel of books under the arm. To avoid this result, if books are carried under the left arm one day, they should be carried under the right arm on the next, and vice versa.

One of the most common defects is that of round shoulders; Fig. 142. This results, primarily, from the mere failure to keep the shoulders back and the head erect. Nothing is more fatal to grace and good general appearance than this deformity and many a person whose face is not handsome makes a very pleasing impression because of a graceful form due to a perfectly upright head. "Head erect, shoulders back and chin in" are three simple directions for good carriage. Standing and sitting erect are the means for developing a sound, handsome body, and using hammocks, reclining chairs, and leaning against sup-

ports when standing are the common habits responsible for many crooked, wrongly developed figures; Figs. 143 and 144.

*All powers that are not used are soon lost, and a perfect body requires the harmonious development of all its muscles, without the excessive development of any at the expense of others.*

### DISEASES OF MUSCLES AND BONES

The tuberculosis bacillus sometimes attacks the bones, especially at the joints, producing serious conditions such as **hip-disease.** Frequently a trouble called **rheumatism** appears around the joints and interferes with their ready action. It is frequently an ailment of persons beyond middle age, though it is not uncommonly found among young people. Its cause is not yet known nor any method of preventing it, except to avoid too rich a proteid diet.

**Tetanus,** commonly called **lock-jaw,** is an extremely serious disease, which is characterized by a peculiar state of the muscles. It is caused by a well known bacterium which lives in the soil; Fig. 145. If a person receives an injury from an instrument that has been lying on the ground, a rusty nail, for example, some of these *tetanus bacilli* may enter through the wound. Many cases of this disease have followed wounds from toy pistols and other fireworks on the Fourth of July. If these bacilli get into the body, they grow and multiply, producing one of the most deadly poisons known, which is absorbed by the blood and carried over the body. The most noticeable symptom is that the jaw muscles contract so tightly that the mouth cannot be opened, hence the name **lock-jaw.** The muscles in the rest of the body soon undergo a similar contraction. The disease is extremely painful, and practically always fatal. No sure remedy for tetanus is known, though an antitoxin somewhat like that used for diphtheria

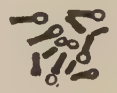


FIG. 145.—TETANUS BACILLI i.e. bacteria that produce lock-jaw.

is now used successfully in many cases. The best method of combating this disease is by preventing it. If wounds are carefully cleaned so that no germs are left in them, the danger is removed. A deep wound made by a dirty object should be cleansed and disinfected with particular care. It is always a risk not to put such a wound in the charge of a physician. The deeper the wound and the more dirt which gets into it, the greater the danger.

It is becoming common procedure nowadays to inject with tetanus antitoxin those who have received deep wounds made by dirty objects, or indeed any wounds that have not been treated from the start with some disinfecting agent. This plan prevents the development of tetanus from such wounds and is far more likely to be successful than to try to cure a case after it has developed. Enormous quantities of this antitoxin have been used for this purpose with the soldiers who have been wounded in the recent European war.

## CHAPTER XVIII

## THE NERVOUS SYSTEM

Without the nervous system, the human body would be in the lamentable condition of a fully equipped factory with plenty of willing workmen, which stands idle because of the lack of a manager. Not a motion in the whole mechanism would be possible and not an impulse or thought be experienced. If the body were not alive, this want of power of motion would be perfectly natural, but in the living body this helplessness through lack of direction is one of the saddest of sights. A yet sadder one is that of a living body showing a large amount of activity, but not properly regulated. Such a condition we sometimes see in idiots or insane people: life in plenty, action in abundance, but all ill-applied and reaching no useful end. It is as if the factory were running night and day, burning coal and using up material, but turning out no useful product.

The functions of the nervous system are numerous. It must direct and control all visible movements; it must also control many invisible activities like the secretions of glands, the movements of the intestine and the beating of the heart. It is, moreover, concerned with higher functions, such as feeling, thinking, remembering, willing and other mental acts, many of which, though frequently never apparent in action, make up the most important part of our lives.

The **central nervous system** consists of the brain and spinal cord, which are not separate organs but parts of the same mass of tissue, and contain most of the nerve cells concerned in the higher functions. The delicate structures of the central nervous system are placed within strong protecting bones, but that they may have communication with the

rest of the body, they are connected with the individual organs by a network of nerves and nerve endings, which make up the **peripheral nervous system.** In addition to the central and peripheral systems, there is a third, partially independent collection of nerve fibres and cells, which is known as the **sympathetic nervous system.**

### THE CENTRAL NERVOUS SYSTEM

**The Brain.**—In all the higher animals, the brain is present and is the seat of the mental life. One can scarcely say that it is more important than the heart or the kidneys, for without any one of them life could not continue; but it is the sole directive agent of the higher functions.

The brain is inside the skull, the bones surrounding it and making up the brain box being called the **cranium.** Where the backbone joins the skull the spinal cord passes into the cranium through a large opening, the **foramen magnum.**

**Membranes about the Brain.**—Applied closely to the inner surface of the cranium is a tough lining called the **dura mater.** This serves at the same time both as a brain covering and a sheath, which functions as the periosteum does in other bones. Closely applied to the brain itself is a thin, rather delicate covering, the **pia mater.** This follows the brain surface completely, dipping into every groove and covering every wrinkle. The *pia mater* is very full of blood vessels, and thus forms both a protecting and a nourishing agent.

Between the *dura* and the *pia mater* is a thin tubular membrane, the **arachnoid,** the space within it being filled with the **arachnoid fluid.** This serves the very apparent purpose of a cushion. The brain is exposed to countless jars as one walks or merely moves the head, and it is easy to see how much difference this fluid cushion must make in saving this delicate nerve center from wear and tear.

**Main Divisions of the Brain.**—All animals with backbones show the same brain parts as man. Assuming the brain to be

free from all its coverings and looked at from above, little is seen but two large hemispherical masses, separated by a deep fissure. These masses make up the **cerebrum,** and are called the **cerebral hemispheres.** If the brain is tilted forward so that the back part of the cerebrum is visible, there comes into view the **cerebellum,** which also shows an open groove between its right and left halves. Below the cerebellum is the **medulla,** which extends downward and passes, without any special line of separation, into the **spinal cord.** These parts are shown in side view in Figure 146.

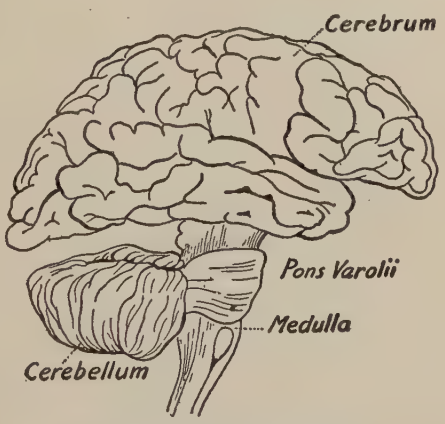



FIG. 146.—THE HUMAN BRAIN
Shown from the side with the cerebrum and cerebellum separated from each other

Viewed from below (Fig. 147), the same structures can be recognized, and the **olfactory** or **smelling nerves** should also be noticed under the front lobes of the cerebrum. Going from front to back, observe next between the two cerebral hemispheres the large **optic nerves** going to the eyes, the nerve from the right side, and the one from the left meeting in the middle line. The place where these fibres mingle forms an X-like structure, called the **optic chiasma,** just beneath which is the small, round **pituitary body,** whose function is not exactly known. Behind this, notice on each side a lengthwise ridge. These two ridges, which are called the **crura cerebri,** converge backward until they become the right and left halves of the spinal cord. Back of the crura

cerebri is a prominent transverse band of fibres, the **pons Varolii,** which connects the right half of the cerebellum with the left, going in front of (ventral to) the spinal cord as it does so. Behind the pons is the **medulla.**

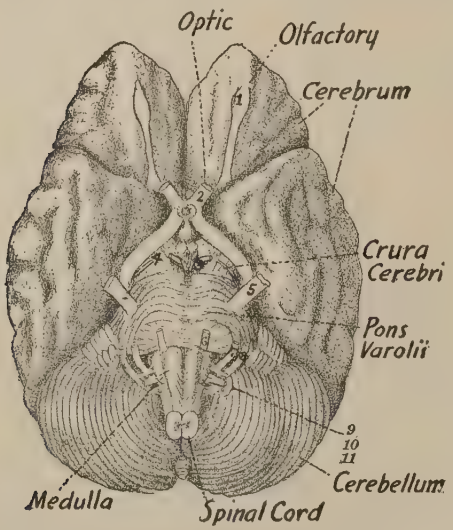



FIG. 147.—THE BRAIN AS SEEN FROM BELOW[1]

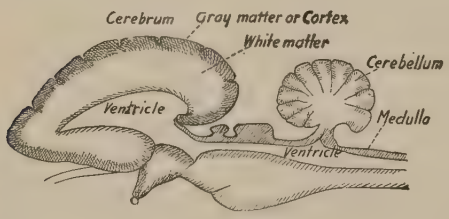



FIG. 148.—DIAGRAM

Representing the divisions of the brain as lying in a straight line and separated from each other and showing the ventricles within.

The outer surface of the brain in some of the lower animals is perfectly smooth, but in man the cerebrum and cerebellum show many furrows dipping into the surface and separating rounded ridges, called **convolutions.** If a number of different specimens of the brain were examined, the main convolutions would be found to occur in the same relative positions in each. The cerebellar convolutions are always much narrower than those of the cerebrum and are more noticeably arranged in groups, with the ridges

[1] The cranial nerves are numbered: 1, Olfactory; 2, Optic (at their place of crossing [optic chiasma] the pituitary body is shown); 3, Oculomotor; 4, Patheticus; 5, Trigeminal; 6, Abducens; 7, Facial; 8, Auditory; 9, Glossopharyngeal; 10, Vagus; 11, Spinal accessory; 12, Hypoglossal.

approximately parallel or concentric, as is shown in Figure 147.

**Cavities in the Interior of the Brain.**— The interest which anatomists have felt in the brain has led them to make minute studies of its interior, but we shall notice only a few points. If the cerebral hemispheres be forced apart at the top, they are found to be joined together toward their centers by a large cross band of fibres, called the **corpus callosum.** There are also empty spaces in the brain. We know that this is true of the larger bones but we seldom think of cavities in the brain. If we assume the parts of the brain to be arranged in a straight line, one part behind the other, and the whole to be cut in a vertical plane near the middle, the cavities or **ventricles** will appear as in Figure 148, as a continuous series from the front through the brain and down the cord. It must not be supposed that these passages are open cavities, for the sides of the ventricles are in close contact with one another. They are, however, cavities, just as there is a cavity in a rubber water bottle when it is empty even though its sides are collapsed. Just what purpose these cavities serve is not known. The fluid in them is like that between the *dura* and *pia mater* coverings, of a thin watery consistency, and may act in connection with the blood from which it is derived, as a means of nourishing the brain.

**Gray and White Matter.**— If a part of the brain be cut open, its tissues will appear to be of two sorts: on the outside or **cortex,** is **gray matter,** and inside this, **white matter;** Fig. 148. This difference in color would be in itself of no consequence if the microscope did not show these layers to be made up of essentially different materials. The greater part of the gray matter contains numerous **nerve cells,** while the white matter underlying the gray, appears to be made up almost entirely of **nerve fibres,** which are, essentially, outgrowths from the nerve cells. This distribution of the white and gray matter in the different parts of the brain will be noted as each division is considered.

## THE CEREBRUM AND ITS FUNCTIONS

The cerebrum is by far the largest and most important part of the brain and is the real center of thinking, perceiving, willing and indeed of consciousness. Its primary activities are carried on by the nerve cells located in the gray matter or cortex. The most important experiences in our lives are carried on through the activities of these cells. It is much easier to think of cells of protoplasm as giving rise to materials like saliva or bile, than to imagine them making thoughts. The former process is called secretion; but shall we speak of the cells of the brain as "secreting" or "making" thoughts, or as "containing" memories, which may be drawn on at will? We do not know; but we do know that it is these cells that are the real thinking part of the body.

FIG. 149.—A SECTION OF THE CEREBRAL CORTEX

To show the numerous cells that it contains. The surface of the brain is at the top and the white matter would be at the bottom of the figure.

Figure 149 shows a section of the cortex. It will be noticed that the cells are of several different kinds and shapes, though very few are round and nearly all have several angles or corners from which extend and branch thread-like outgrowths, called **dendrites**; Fig. 11, page 18). There is always one process from each cell that extends much farther than the others and finally ends, either near dendrites of other cells, or else passes down the spinal cord. This long outgrowth becomes the central axis of a nerve fibre, over which messages are either sent or received as the case may be, sometimes for as great a distance as two or three feet. Further description of these nerve cells will be made later (page 310).

Since the white matter consists of fibres and the gray of cells, the conclusion is that in general the white central layers of the brain are made up of fibres arising from the cells that lie near its surface. Every nerve fibre is really a part of a nerve cell, however far from the cell it may extend. This relation of the white to the gray matter should be kept in mind during all our discussion of brain structure and function. If the cells of the cerebrum were inactive the heart beat and breathing might continue; but there would be no powers of sensation, of thought, of judgment or of volition, no emotions, no anticipation nor memory; lacking the cells of the cortex one could not consciously move any muscle of the body. Thus, *in the cells of the gray matter of the cerebrum reside all powers of sensation, of voluntary motion and what we call intellect.*

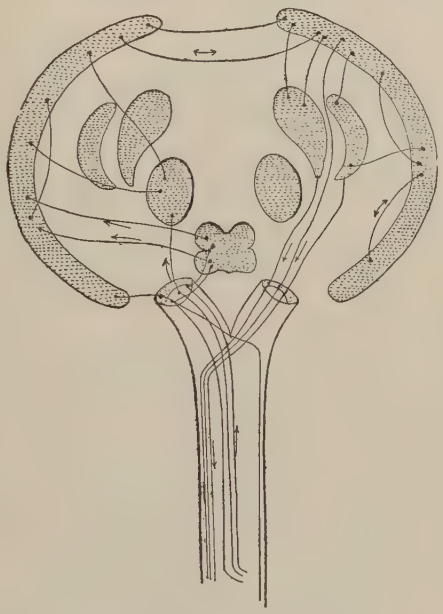


FIG. 150.—DIAGRAM
To show the courses of fibres through the brain. It will be seen that all paths to or from the spinal cord cross, those *from* the brain crossing at the base of the brain, and those *to* the brain crossing lower down. Outer shaded area represents the cortex of the cerebrum; inner shaded areas are subordinate nerve centers. (Landois)

One other very important fact should be mentioned here; the cells in the right half of the cerebrum are, to quite an extent, connected by fibres with the left side of the body, and those

of the left half with the right side of the body. Doubtless the student has known of a case where some part of a person's body is paralyzed. As a rule, whichever side of the body is affected, the trouble is on the opposite side of the brain. As a proof of this, if the brain of an animal is laid bare and then stimulated in spots with electricity, the movements which result are always on the side of the body opposite to that on which the brain is stimulated. Paralysis sometimes results when a blood vessel has broken and a clot causes pressure on some part of the cortex; if the clot can be removed, the patient may entirely recover. Other causes of paralysis will be noted in connection with the spinal nerves.

The fibres in the center of the cerebrum are concerned wholly with carrying nerve messages or impulses, never in originating or receiving them. Figure 150 shows the courses of some of these fibres of white matter. In the performance of one's varied motions, it is evident that the most intimate connection between the two sides of the brain must be established. The right and left sides of the body, and both arms and legs are doing things which must be directed toward the same end in an orderly manner. The figure shows that some fibres put the two halves of the cerebrum into complete communication with one another. The different cells of the same side are also connected since they govern such different muscles and must be completely harmonized in their actions. No picture can represent accurately all of these fibres, nor would it be possible to follow them all, so numerous are they. It is necessary merely to keep in mind that these cells are all in ready communication with one another, and thus work together in the control of the thousands of muscle movements in the body.

**Cerebral Localization.**— The use of these fibres becomes very easy to understand when we note that certain parts of the brain have special work to do. The functions of the cells

of the middle, superficial part of the cerebrum have been particularly investigated and it has been shown that some of these control the muscles of the arm, others those of the leg, those of the neck, those of the eye and so on. The whole surface of the cerebrum can not be mapped out in this way. Figure 151 shows the main areas of the brain and the parts of the body which they control. All parts of the brain cortex have not yet been proved to have clearly defined uses. Indeed, there are on record instances in which, through accidents, parts of the human brain have been removed, and yet the injured person showed no unfavorable effects, in fact, almost entirely recovered.

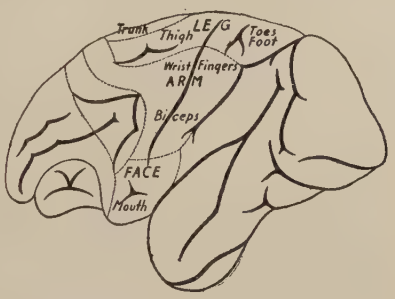



FIG. 151—THE BRAIN OF A MONKEY
Showing the parts of the brain that control movements of different parts of the body. (Horsley and Schäfer)

## THE CEREBELLUM AND ITS FUNCTIONS

We have already noticed that the external surface of the cerebellum shows a great complex of narrow ridges, separated by grooves. If this organ is cut open, the cut surface shows, as does the cerebrum, the white and gray matter, but it is arranged somewhat

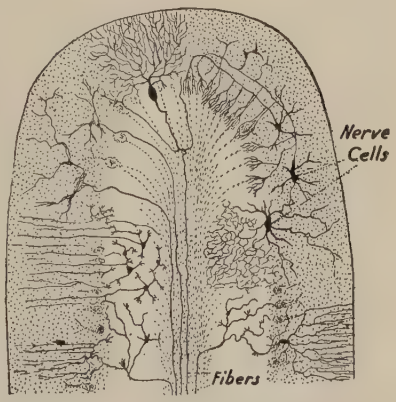



FIG. 152.—A SECTION OF THE CEREBELLUM
Highly magnified. Some cells in this organ have especially long and numerous dendrites. (Obersteiner)

differently. Cells and fibres are also the main materials of which the cerebellum is made. Figure 152 shows their arrangement diagrammatically. The nerve cells are of several kinds, some showing very complex and some very simple bunches of dendrites. In every case, the cells are located near the surface, while the fibres make up the centre of each lobe.

The real use of this part of the brain is not thoroughly understood, but there are two main functions which are usually ascribed to it: first, that of a **co-ordinating centre.** Messages starting from cells in the cerebrum, on their way to the different parts of the body, go to the cerebellum and are there brought together in such a way that the movements which they produce take place in an orderly, related manner.

In every human being several activities are going on at the same time. In ordinary walking, for example, the muscles in one leg are contracting while corresponding muscles of the other are relaxing. While a person is walking it is entirely possible for the muscles of the neck to turn the head, for those of the tongue and mouth to be concerned in speaking, and for those of one hand to be contracted about a package or umbrella. Thus, although one does not frequently think about it, all our habitual activities involve a very complicated nervous mechanism. This direction of movements so that many muscles may work together toward a single end is called **co-ordination,** and is one of the functions of the cerebellum. Impulses provoking movements start in the cerebrum, but are regulated in the cerebellum. An animal from which the cerebellum has been removed is unable to control or direct the movements of the various body muscles and cannot perform even the slightest action in an orderly, straightforward manner.

A second function of the cerebellum which has been emphasized by some physiologists is that of a **relay station** for outgoing impulses from the cerebrum, strengthening the force of nerve messages on their way to the lower muscles of the

body. Acts of thinking, too, seem to be somewhat weakened, becoming less virile and positive, in the cases where the cerebellum has been impaired by disease or some other cause. However, this function of the cerebellum as a message-strengthening organ cannot be regarded as so important, or so certainly known, as its co-ordinating influence.

### THE MEDULLA

The medulla is connected with the control of respiratory and circulatory organs. It lies beneath the cerebellum and its lower end is continuous with the spinal cord from which it is not distinctly separate. Large bundles of fibres, crura cerebri, extend from its upper end into the cerebrum.

If the tissues of the medulla were carefully examined, it would show a complex mixture of nerve fibres and nerve cells, whose arrangement would differ very much, depending on whether the cut were made through the anterior, middle or posterior portion of the structure. We need merely note that among these fibres there are patches of cells, sometimes called " nuclei," from which most of the cranial nerves take their origin. The fibres themselves come from cells which are either in the cerebrum or lower down, in the cord; so that the medulla becomes a great complex of paths for messages passing in either direction.

So far as its fibres are concerned, the medulla simply transmits messages from the brain down to the spinal cord, and in the reverse direction, but its nerve cells give it some other functions. The particular activities which are controlled by the nerve cells of the medulla have been determined by removing from some animal the other parts of the brain and then noting carefully what powers have been taken away and what powers are left. Such an animal keeps on breathing, and the blood vessels still continue to expand and contract, so we say that the medulla contains **respiratory** and **vaso-motor centers.** In the medulla is also the **cardio-inhibitory center,**

from which messages go over the vagus nerves to check the beating of the heart; see page 145. Although the above are the most important, there are other centers located in the medulla; but, in general we may say that *the medulla is the seat of all involuntary activities.*

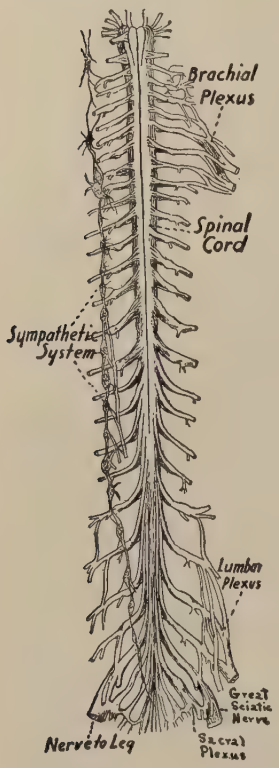



FIG. 153.—THE SPINAL CORD
With the spinal nerves attached. Upon one side is shown the sympathetic system. (Thompson)

### THE CONNECTIONS BETWEEN THE BRAIN AND THE BODY

The brain, shut up as it is within the bony walled cranium, may be compared to a telegraph operator in his small office. It is quite remote from many important organs of the body, but by means of innumerable nerve fibres, corresponding to telegraph wires, it is connected with them all, as the telegraph operator may be in communication with the rest of the world. The next step in our discussion, then, is to study the spinal cord, which is the main cable, as it were, of nerve fibres.

### THE SPINAL CORD

Since the term **spine** is commonly applied to the backbone, the large nerve which passes down through it is naturally called the **spinal cord.** Notwithstanding the innumerable twists and bends which the body makes, the cord is perfectly protected from strain and injury. Figure 123 shows that each vertebra is essentially an irregular ring of bone encircling an opening; when a number of vertebræ

are arranged one on top of the other, these openings form a long tube, the **spinal canal.** In this is the spinal cord, continuous with the brain above and terminating by dividing into branches in the lumbar vertebræ, Fig. 121. It is nearly uniform in size throughout its length, though it enlarges somewhat as it merges into the brain and is somewhat larger than elsewhere in the region between the shoulders and in the lumbar region, or "small of the back." Its average diameter is about three-quarters of an inch.

Like the brain the cord is protected by two sheaths, the **dura mater** and the **pia mater,** which are continuous with

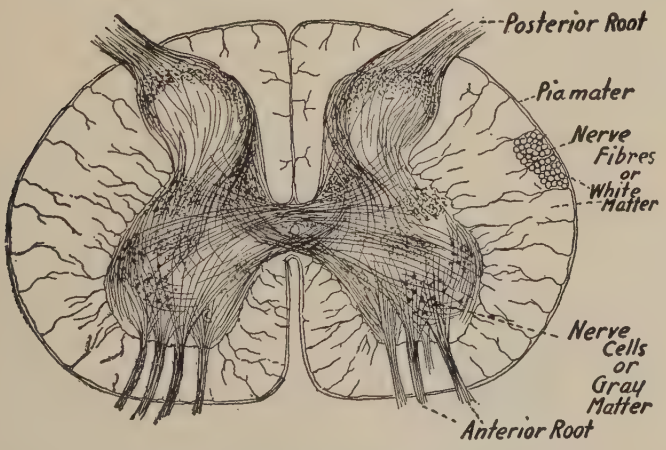



FIG. 154.—A CROSS SECTION OF THE SPINAL CORD
The white matter is really filled with nerve fibres but in the figure these are shown at only one point.

those of the brain, and like them in every way, save that the dura mater is not grown to the vertebræ as it is to the inner side of the cranial bones. Arachnoid fluid is present and forms a cushion about the cord as it does about the brain.

**Structure of the Cord.**—The cord is cylindrical in shape and divided into right and left halves by deep grooves, one

on its anterior and one on its posterior surface, the anterior being more open and more shallow than the posterior. The two halves, which are clearly shown in Figure 153, are held together by a central connecting portion, about one third of the diameter in width.

The grooves of the cord are still better appreciated by a study of a cross section; Fig. 154. Such a section, too, shows that the cord, like the brain, is made up of two kinds of material, nerve fibres and nerve cells, though in reversed relations, the outer layers of the cord being of white, fibrous matter, and the inner of gray, cellular matter. Recognizing that the nerve fibres simply conduct impulses, while the nerve cells have other more complex functions, it will be evident that the cord has these two different classes of activities. Since the process of conduction is the simpler matter, we shall study it first.

**The Cord as a Conductor of Impulses.** —Messages sent through the cord pass either up or down in the white matter; but do impulses going up the cord follow the same paths as those going down? This question has been answered by experiments on some of the lower animals which are constructed essentially like man, and also by observation of the results in human beings in which the cord is diseased or has been injured by accident. These observations have shown that if a part of the cord is disabled, sometimes sensation and some-

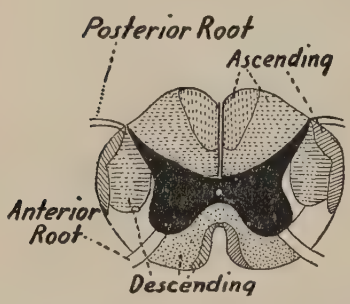



FIG. 155.—DIAGRAM OF A CROSS SECTION OF THE SPINAL CORD
Showing the parts that carry messages up (ascending) and those that carry messages down the cord (descending). (Modified from Flint and Landois)

times the power of motion is lost below the injured point. If the power of motion is lost, e.g. the motion of the leg, then the injury must be in a **descending tract,** where the messages that pass from the brain down to the leg have been interfered with. If the person loses the sensation of feeling so that he has no consciousness of anything that may touch a given part of the body below the injured spot, then it is assumed that an **ascending tract** has been severed.

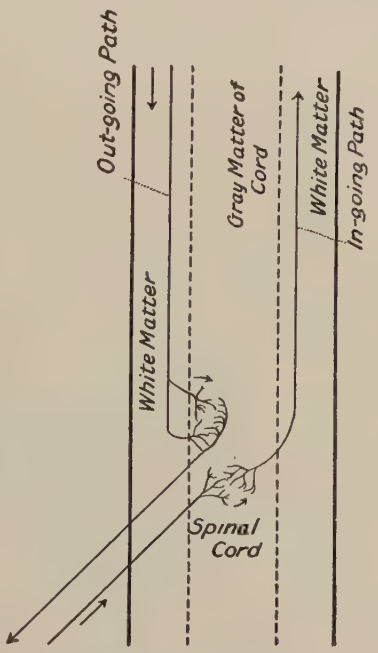



FIG. 156.—DIAGRAM
Showing the course of the ingoing and outgoing impulses in the cord.

By these studies the areas which are devoted to impulses going in one direction or the other have been determined approximately as in Figure 155. Roughly speaking, all ascending impulses go up to the brain either on the posterior side or on the right and left lateral regions near the surface; while the descending impulses pass downward on the anterior side or in the deeper layers of the lateral regions.

One unexpected fact, however, comes to light in studying the nerve paths in the spinal cord. An injury on one side of the cord is, as a rule, accompanied by loss of sensation on the other side of the body but not on the same side as the injury. The conclusion is that messages brought into the

spinal cord pass immediately to the other side and ascend there. Curiously enough, however, an injury destroys the power of voluntary motion on the same side as the injury, but not on the other. Hence messages from the brain pass down the cord on the same side as that to which they finally go. Figure 156 shows these facts diagrammatically. These messages from the brain going down the cord cross over from left to right and vice versa, higher up, mainly in the medulla, so that all messages going to either side of the body start from the other side of the brain. Thus, the sensations and motions of each side of the body are connected with and controlled by the cells in the cerebral hemisphere of the other side. Although there are a few exceptions to this arrangement, this is, in the main, the relation of the spinal cord to the rest of the body.

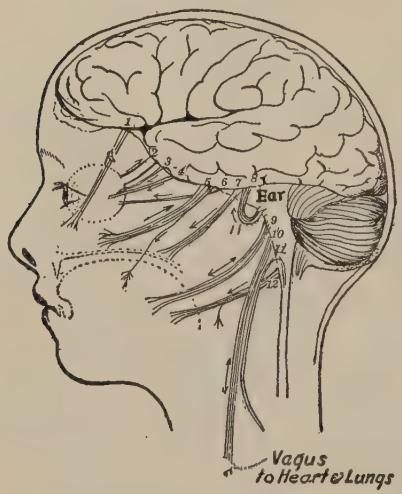



FIG. 157.—DIAGRAM
Showing the distribution of the different cranial nerves. The numbers indicate the number of each nerve, and the arrows show whether each is afferent or efferent.

### THE PERIPHERAL NERVOUS SYSTEM

The nerves over which messages are brought to the spinal cord or the brain and those over which messages are sent out compose the peripheral nervous system. These nerves are classed in two groups: (1) the **cranial nerves** which go to or leave the brain directly without entering the cord; (2) the **spinal nerves** which enter and leave the cord.

**The Cranial Nerves.**—The cranial nerves are twelve in

number, arising directly from the brain and passing out of the cranium to supply, chiefly, the organs of the head; Fig. 157. The muscles of the head are controlled by them, sensations from the face, the nose, the eye, the ear and the tongue are received through them. Some of the more important of these we shall consider in the following chapter.

**The Spinal Nerves.**—Between the neural arches of each two vertebræ enough space is left for a nerve of considerable size to pass from the spinal cord on each side. There are thirty-one of these spinal nerves on each side of the cord. Five of them unite to make up the **brachial plexus**, i.e. the nerve combination which supplies the arm; four form the **lumbar plexus** and thence pass down each leg as one nerve; Fig. 153. The rest supply the numerous organs of the neck and trunk proper. Figure 158 shows that a spinal nerve does not leave or enter the cord in one place as a branch grows out of a tree, but arises by two roots, one being continuous with the gray matter in the anterior part of the cord and the other with that in the posterior part. These two roots join to form one nerve; before their junction, however, a swelling, a **nerve ganglion,** occurs on the posterior root.

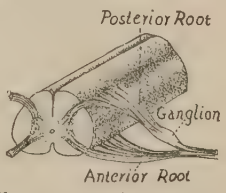



FIG. 158.—A BIT OF THE SPINAL CORD
Showing the method of origin of the spinal nerves by two roots.

The precise function of these two roots has been ascertained by experiments upon animals. If, for example, the posterior roots of all the nerves going to some one organ, e.g. the leg, have been cut, it is found that nothing touching the leg, not even a burn, is felt in the least, but it is still possible for the animal to move the leg or any part of it. This result shows that all *sensory impulses,* all messages having to do with feeling, as we say, pass from the leg into the spinal cord over the posterior roots of the spinal nerves. The function of the

posterior roots of all the spinal nerves of the body, therefore, is to carry sensory messages or impulses which are always *passing into* the cord or brain, and are frequently called **afferent impulses,** and the nerves concerned, **afferent nerves.**

If, on the other hand, the ventral or anterior roots are cut and the posterior left intact, the animal so injured is unable to move its leg, but can feel perfectly anything in contact with it. From this, one decides that the impulses from the brain or cord which go to the muscles of the leg leave the cord by the anterior roots. The anterior roots of all spinal nerves, then, carry *motor impulses.* Motor impulses always *pass from* the cord or brain; they are called **efferent impulses** and the nerves concerned in carrying them, the **efferent nerves.** After the dorsal and ventral roots (afferent and efferent) unite into a single trunk, the spinal nerve resulting is a mixture of both kinds of fibres, though their functions remain distinct. In the various figures in this chapter the direction of the arrows indicates the direction of the impulses that pass through the various nerves. The number of nerve fibres that thus enter or find exit through the cord is very large. There are many hundreds of thousands of them in the thirty-one pairs of spinal nerves and by means of them every part of the body is brought under the direct influence of the spinal cord and brain.

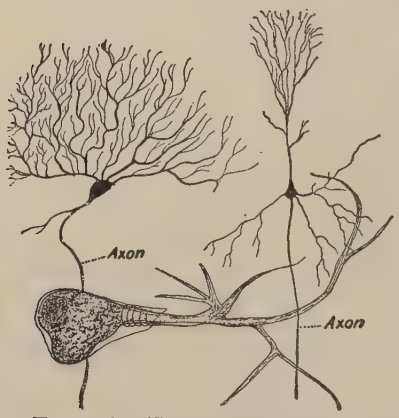



FIG. 159.—THREE NERVE CELLS
In two of them is shown the axon, or axis cylinder, of the nerve connected with the cell.

**Structure of Nerve Fibres.**—In the opening chapter the minute cells which make up the body were described. These

cells are essentially alike, in that each consists of a bit of protoplasm, containing a nucleus. Nerve cells differ from others, of course, in their peculiar function, and it would be interesting indeed to know how they do their work of thinking, memorizing, inventing, etc., but this no one can tell. They also frequently differ from others in their very irregular shape (Fig. 159) and in the outgrowth from most of them of a long process, the **axon,** or **axis cylinder,** the work of no other cells requiring such connection with parts of the body at a distance from them.

A portion of a nerve fibre is represented in Figure 160. It consists of a very fine central thread, the above-mentioned

FIG. 160.—A SHORT PIECE OF A NERVE FIBRE
Very highly magnified.

axis cylinder, which is continuous from its point of exit from a cell in the brain or spinal cord, to its end, e. g. in some muscle, gland or skin cell. Covering this axis cylinder, which is the real conducting fibre of the nerve, is the **medullary sheath,** which is of material different from that of the fibre and contains considerable fat. It seems to act as a covering to prevent impulses which are passing along the fibre from jumping across into other fibres lying close by, thus serving something the same purpose as does the insulating covering of gutta percha around an electric wire. This medullary sheath is interrupted at short intervals called **nodes** (Fig. 160) and between every two nodes there occurs a **nucleus** showing the medullary sheath to be made up of many cells. Outside the whole is a thin covering, the **primitive sheath.**

On the other hand, since this sheath contains fats, the nutrition of the nerve fibre has been regarded as its main function. There is little to support this view, however.

In the spinal nerves and every nerve leaving or entering the brain or cord there are very many of these minute fibres running together in a bundle. It is this bundle of nerve fibres which is meant when the term **nerve** is popularly used; Fig. 161. Even in the bundle, each fibre has its medullary and primitive sheaths; only after the fibre has entered or before it leaves the brain or spinal cord is the primitive sheath left off. In the white matter of the central nervous system the fibres have uninterrupted medullary sheaths, i. e. not divided into nodes and internodes, and there are no external sheaths. In very exceptional cases, as for example, the nerves going to the nose, which is so near the brain, both medullary and primitive sheaths are wanting.

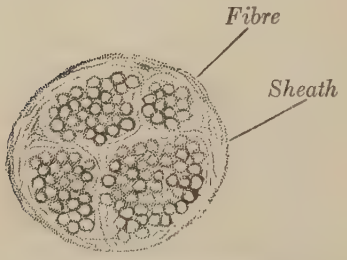



FIG. 161.—A CROSS SECTION OF A NERVE
Showing it to be a bundle of fibres held in a sheath of connective tissue.

**Replacement of Nerves after their Injury.**—Whenever a person cuts or otherwise injures the skin or any muscle just beneath it, healing begins almost at once and soon there is enough new tissue formed to repair the wound completely. When, however, one of the long nerve fibres which pass from the cord or brain to the surface of the body is cut off, repair takes place in a very different way. The two ends of the cut nerve will never come together again and mend, but the part of the fibre between the point of injury and the organ to which it goes dies. The stump between the injured place and the cord or brain often does not deteriorate at all, or only for a very short distance.

A new nerve to replace the portion of the nerve peripheral to the injury is formed from material made by the cells of the old primitive sheath. These increase in number along

the line of the old fibre, become changed at first into a jelly-like material and later into nerve-fibre substance. This new nerve fibre makes connections with the stump of the old one, and communication is again possible between the cell in the cord or brain and the old nerve ending.

**Nerve Endings.**—As has been pointed out, nerves are divided into two classes: (1) the afferent nerves, which bring in impulses from the outside world or from internal organs to the spinal cord or brain; and (2) the efferent nerves, which take impulses out from the cord or brain to the organs which they supply.

Several kinds of afferent nerve endings, or more properly beginnings, in the skin or elsewhere have already been referred to and shown in Figures 112, 117 and 118. In general, they may be said to start in very minute spheres or oblong bodies called **corpuscles.** The nerve fibrils begin here as fine branches either on the exterior or in the interior of these organs. These skin end-organs receive mainly impressions of touch and temperature, an extreme of either taking the form of pain.

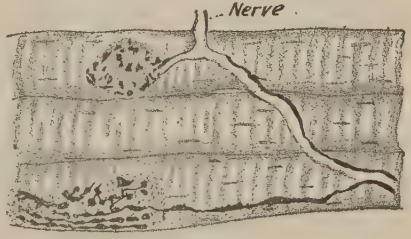



FIG. 162.—THE ENDING OF A NERVE IN MUSCLE FIBRES

The end organ of a motor nerve. (Bohn & Davidoff)

The efferent nerves are distributed almost entirely to muscles and glands and excite these to action. The manner in which nerves end in muscles is diagrammatically shown in Figure 162. It is not possible to say just what happens in a muscle or gland when a message is delivered to it. The muscle contracts or the gland secretes, but just what change in their protoplasm excites these activities is not known.

## CHAPTER XIX

## THE NERVOUS SYSTEM—NEURONS, NERVE IMPULSES AND REFLEX ACTION

It has already been noted that the whole nervous system is made up of nerve cells and nerve fibres, which indeed form the basis of the gray and white matter, respectively. The fibres and cells are not separate structures but each fibre is a part of some cell; and thus it comes about that the whole nervous system is composed of these units, each consisting of a cell with its connected fibre or fibres. These units are called **neurons** (one of these is pictured in Figure 11). Each consists of a nerve cell with its nucleus; extending from the cell are dendrites and one axis cylinder, at the distal or outer end of which is a nerve ending.

A neuron may receive an impulse through its axis cylinder and send it out through its dendrites, or it may receive the impulse through its dendrites and send it out through its axis cylinder. In either case it is as the neurons act, each by itself, and each in connection with the other neurons, that the functions of the nervous system are performed. Some of them constitute the thinking and willing part of the brain; others in the cord and elsewhere are the servants of those in the brain, since they carry messages to and from the brain, though they have, besides, important functions in connection with reflex actions. We shall consider first those which carry impulses to the brain, then those that carry impulses away from it and finally those concerned in reflexes.

## THE NEURONS AS TRANSMITTERS OF IMPULSES

**Ingoing Paths.**—We have already learned that the posterior roots of the spinal nerves carry messages inward and that upon each posterior root there is a swelling, the so-called spinal ganglion; Fig. 158.

Inside this spinal ganglion are the cell bodies of a large number of neurons. From each cell body extends a single projection or axis cylinder, which soon divides, one branch passing inward to the spinal cord, the other outward in the nerve trunk into the body, finally ending in some sensitive part, e.g. the skin; Fig. 163. If the skin is touched in any way at that point, an impulse will start and go rapidly inward on the fibre, pass the neuron cell body in the ganglion and continue into the cord. In the cord, as shown also in Figure 164, the fibre again divides, one fibre going upward and the other downward. The branch passing up the cord soon divides into a number of twigs, forming at *c* a brush of fibrils called **arborizations.** Close to these arborizations begin similar divisions of another fibre whose cell body is higher up, possibly in the brain itself; Fig. 164*d*. The impulse which enters the cord may thus

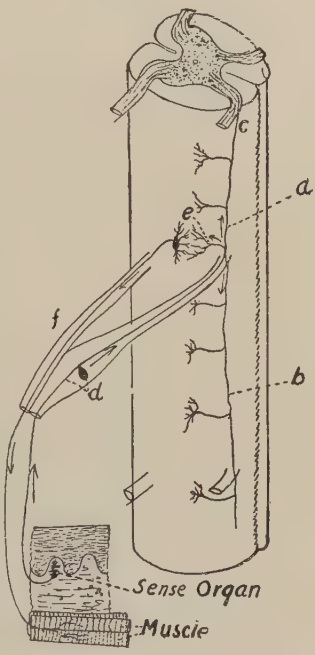



FIG. 163.—DIAGRAM ILLUSTRATING A SIMPLE REFLEX ACTION

The impulse from the sense organ passes in over the nerve fibre, *a*, and may pass up to the brain over *a-c*. But a part may be switched off through *e* down the fibre *f* to the muscle, causing it to contract without the aid of the brain.

jump from one of these fibres to the other through their tuft-like endings and then go to the brain.

But there is another direction which the impulse from the skin may take after its arrival in the cord. The branch in the cord marked *a* in Figure 164 also has side branches ending in arborations *e*. If the ingoing impulse passes out into these, it may jump across into the fibrils of another neuron whose fibre, *f*, does not lead to the brain at all, but passes out through the anterior motor root of the spinal nerve to some muscle. The result will be movement at the end of the motor fibres. From the course which the impulse in this last instance took, it is evident that the resulting motion must have occurred without the mediation of any conscious centers in the brain, since only the cells of the gray matter of the spinal cord were concerned in the process. This production of movement in a muscle without the "consent" of any conscious centers of the brain is called a **reflex action.** Involuntary movements of both voluntary and involuntary muscles occur very frequently in the body and play an important part in life processes. They will be considered at greater length a little later.

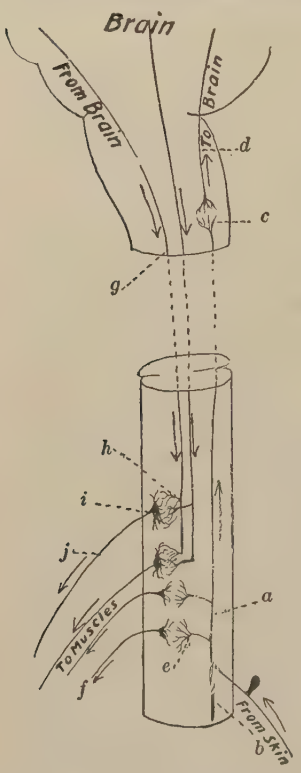



FIG. 164.—DIAGRAM
Illustrating the course of messages to and from the brain through the spinal cord.

From an examination of Figure 164 it is easy to see that two results might follow the arrival in the cord of an impulse

from the skin: a part of the impulse might go into the side branch, *e*, and give rise to a reflex movement, while the rest of the impulse could take the path, *a*, leading to the brain and there produce sensation. Influenced by this sensation, the brain might send down a message through the fibre, *g*, which would result in conscious movement, in addition to the reflex response. Suppose, for example, a barefooted boy steps on a thistle. He jumps off quickly (a reflex action). In a fraction of a second he feels the prick and acts accordingly, but he jumped before he was conscious of the pain.

The neurons described are those in the spinal cord and spinal ganglia, but there are a large number in the brain itself. The details of their structure are slightly different, but their general relation and method of working is the same.

**Outgoing Paths.**—Although the gray and white materials of the brain cortex have been previously referred to merely as cells and fibres respectively, it is necessary to realize that the brain material is a mass of neurons and that the whole nervous system is made up of these same units. The white material is not independent of the gray; it merely consists of the axis cylinder fibres of the neuron cell bodies of the gray matter.

The cell bodies of these brain neurons receive all messages brought to them, and are the centers of the thinking processes. Decisions are made in them and they start impulses outward to any part of the body which they have decided to move or influence. These impulses pass directly downward over an axis cylinder (Fig. 164 *g*) or nerve fibre, which finally ends somewhere in the cord in a bunch of arborizations, like those already described; Fig. 164 *h*. Very near these fine endings are the dendrites of another neuron body, *i*, and into these the descending impulses pass. The long axis cylinder of this last neuron (Fig. 164 *j*) passes out through the anterior or ventral root of a spinal nerve, and extends directly, with no further interruptions or "relay neurons", to the special

organ which it is to supply. In this way, impulses started by the brain neurons eventually reach the muscles to be moved or the tissue to be innervated.

## REFLEX ACTIONS

We have already noted that a message coming into the cord from the body may, on occasion, be switched off onto side branches of the fibre it was traversing, jump from its terminal arborations to the dendrites of a neighboring neuron, and go outward over the anterior root of a spinal nerve without immediately going to the brain. There are some further aspects of these reflex actions which should be noted, for an almost infinite number of movements and minor functions of the body, as well as many very important ones, are thus performed.

Probably every person makes more movements unconsciously than consciously. If his attention were especially called to each one of his actions, they would immediately become matters of all-absorbing concern to him, and would take so much of his time that he would be able to attend to nothing but the simplest activities. Suppose, for example, that one had to think definitely about the contraction of each muscle concerned in walking, whenever he took a step; suppose he had to deliberate about the contraction of every muscle concerned in winking every time he moved his eyelids; suppose that every time his clothing touched him at any point, a message were sent to his centre of consciousness in the brain. The nervous energy required would be almost incalculable, and the maintenance and regulation of life would be impossible.

We have already found that the essential peculiarity of a reflex movement is that it is performed without the mediation of any of the conscious centers of the brain. These responses can indeed be obtained in animals from which the

brain has been entirely removed. The fact that the brain of a frog can be taken out, and yet the tissues of the body remain alive for a considerable time (even the heart may go on beating) makes the frog an especially favorable animal for this study. Of course, such a frog has no sensations and no ability to make voluntary motions, still it shows some most interesting reactions. If its toe be pinched, it is pulled away quickly; if the tip of the toe be dipped in acid, it will be pulled out promptly. The frog acts as though it had sensations of pain, though, with the brain wanting, we know that it can have none. It moves because the impulses excited in its nerve endings, after reaching the cord, cannot go to the brain, and therefore take one of the side tracks leading across arborations to other neuron bodies, whose axis cylinders pass immediately out to muscles in the part of the body whence the incoming impulse started.

If the frog has its brain, a different result may follow, for the conscious centers will become aware of the pinch in the toe and the animal may decide to jump, instead of simply pulling its foot away. In this case, the stimulus has of course gone all the way to the brain and back down again, finally passing into the motor cells of the cord, fibres of which extend to the jumping muscles. Thus we see that the same muscles are under the control of two different centers, the conscious center of the brain and one in some other part of the central nervous system, probably in the cord (as we have assumed in the foregoing instances). Save that reflexes are usually quicker, there is no appreciable difference between reflex and conscious movements.

Reflex movements may involve the brain, as well as the cord. This would seem an impossibility; i. e. *the unconscious action of a conscious center*. We get this impression, however, merely because as a rule the brain is thought of as an organ in which only conscious activity occurs. This is a mistake, for not all the cells of the brain are by any means conscious centers.

It is not difficult to cite instances of brain reflexes. If a sudden light flashes in front of the eyes, or if another person shakes a handkerchief or other solid object toward the face, one shuts the eyes instantly. Now a person does not stop to think whether or not he will shut his eyes under these circumstances. They are closed before he realizes it and he himself is opening them carefully, lest the danger is not yet passed. Yet all the nerves controlling the eye muscles come directly from the brain, and the centers from which they arise have acted without the person's conscious volition. Ordinary winking is carried on unconsciously, as we know. The surface of the eye becomes slightly dry, and this condition irritates it. Messages go to the centers controlling the winking muscles, they act and the eyes wink, but the whole process takes place without one's being aware of it. In taking food into the mouth, the movements of the tongue and jaw, while under one's control, nevertheless occur without conscious thought about it. One does not say to himself, "I will now shut my mouth," and afterwards, " I will now open my mouth." These are only two of the innumerable instances of unconscious action on the part of brain centers.

In the above illustrations of reflex actions we have confined ourselves to visible movements. There are innumerable muscular and glandular activities in the body of which one has absolutely no intimation, which also come under this head; e. g. respiratory movements and the movements of the stomach and intestinal walls. Before any of these occur, messages first go from the organ concerned to the central nervous system. For example, when the stomach is empty it lies perfectly passive, but if food is swallowed, the ends of nerves in the stomach are stimulated. They carry the message to some center in the gray matter of the cord or brain, or both, and immediately impulses are sent out over motor nerves to the muscles of the stomach walls, which then begin their

churning action. In the same way, when the food commences to pass on into the intestine, it too begins its complicated movements. One should always remember that these occur only because certain nerve centers are acting.

**Reflex Centers as Servants of Conscious Centers.**—It is hardly possible to overestimate the value of the reflex centers; it is only through them that the conscious centers can carry on the multitude of duties which devolve upon them. One's attention cannot possibly be given to all the little details of living, so these are turned over to the lower parts of the brain and cord, which thus act as a great coterie of servants. To them the whole control of many activities is given after the decision has been made in the conscious centers. Take the common act of walking: one simply directs the lower center to put the walking muscles into proper motion, and then his attention may be wholly devoted to thinking or talking, while the reflex center will superintend the walking movements until he tells it to stop.

That the reflex centers are servants and not independent units is plain when we notice that the higher centers always keep the upper hand, so to speak. With adults, walking becomes a reflex. Still, by an interference, the conscious centers can interrupt the reflex centers at any time, and one can stand in one place as long as he wishes, starting the walking reflex again when he chooses. The eyes may be getting dry, for example, and the tendency of the neurons in reflex centers is to make the winking muscles contract; nevertheless, by giving the matter conscious thought, one can inhibit the winking muscles even until he really suffers pain in the eyeballs. One can also stop the breathing reflex center from acting for a considerable period. Some impulses going out from the brain may, therefore, be negative, or inhibitory as we say, and a great many reflex centers, while acting with partial independence of higher control, are yet constantly liable to its dictates. Others, however, like the involuntary

movements of internal organs, may be practically beyond any control of even the highest centers.

**Relation of Reflex Actions to Training and Habits.**—The reflex centers in all cases consist of the nerve cells, the central parts of some of the neurons or of groups of such cells. But the interesting and important fact is that at the beginning of one's life most of these servants are untrained and cannot perform at all the duties assigned to them in later life. Exactly how these nerve centers are trained, it is impossible to say; but we do know that by being made to do the same thing over and over again they finally learn to do it well, and at last almost without one's consciousness. When a child first learns to walk, for example, his muscles do not readily work out his will, but after some years of practice he no longer thinks of the motions, for the reflex centers take charge of them. *Practice makes perfect*, simply because by constant use the reflex centers may be so trained that they do their work perfectly. When we learned to write we were obliged to attend carefully to the motions of the fingers, to see that all the up-strokes and down-strokes came in the right order. But now, if we are good writers, we do not have to think of up-strokes or down-strokes, hardly of the letters. We think out the ideas we wish to put on the paper, and reflex centers take charge of most of the movements. One becomes aware of this fact when he tries to disguise his handwriting. He finds such a procedure as difficult as he did learning to write, for the muscles and nerve centers are trained to do a thing one way, and continue to do so.

Most of the activities of the child's life have for their purpose the training of these useful nervous centers. His work, his play and his study all have the same end in view; i. e. training for his use a set of faithful servants who will continue for the rest of his life to work in just the way they have been taught in youth. The saying, "It is hard to teach an old dog new tricks," merely expresses the difficulty of training

these nerve centers in any new way after a person has grown up. Education of the body and the mind is thus first of all the training of reflexes. Since one must employ these servants all the rest of his life, it is of the greatest importance that they be trained aright. This is the reason why it is necessary to give so much attention to education, to physical training and to all discipline that develops useful habits of thought or action.

### THE NERVE IMPULSE

We have mentioned the fact that nerve impulses pass over the nerve fibres, and considering the differences in the results they produce, one would naturally suppose that there would be corresponding differences in the impulses; e. g. that the impulse which produces a sensation of light must be very different from one producing a sensation of sound. This is not the case, however. An electric current through a wire may produce different results according to the different kinds of apparatus employed at the end of the wire: it may ring a bell, or produce light in a bulb, or sound in a telephone; but though the results are various, the electric current is essentially the same in all cases. So in the body, the impulse which travels over a nerve is always essentially the same.

No one need be told that nerve messages travel over the nerves very rapidly. One can appreciate no lapse of time between willing to move the fingers and their actual motion, and yet the message must meantime have passed from the brain to the muscles concerned. The rate at which messages pass into the central nervous system, i. e. the rate over sensory nerves, is greater than that at which messages pass out over motor nerves. The former travel inward about 140 feet per second, while the latter travel outward at a rate of about 110 feet per second.

But what is the impulse which travels over nerves? The old idea was that the nerves were hollow and filled with a

fluid, but we know now that this is false. Among other ideas which have been held concerning this question are the following:

1. *The chemical theory* maintains that when a nerve is stimulated, a chemical disturbance passes along the axis cylinder of the neuron involved. This may be compared to the change which takes place in a tiny trail of gunpowder when one end of the line is ignited. The difficulty in accepting this theory is that we should have to imagine the train of material in a nerve to be instantaneously replaced, so that the nerve would be ready to transmit another message at once.

2. *The mechanical theory* assumes that the molecules of the nerve fibres are in close contact, and that any unusual movement of them at one end of a nerve is transmitted through the whole line until it is felt at the other end. Suppose the molecules are compared to croquet balls placed in contact, in a long, straight line. If one at the end is struck the one at the opposite end bounds away from the others, though the intervening balls do not move appreciably.

3. *The electrical theory* looks upon the nerve impulse as an electrical phenomenon. It can easily be excited by an electric shock, it travels very rapidly over the nerve without seeming to produce any changes in it, and in these respects resembles electricity. Then, too, careful study shows that there are electric changes in the nerve when the impulse passes over it. Sometimes an impulse is supposed to jump from one fibre to another as an electric current may jump from one wire to another. On the other hand, the nerve impulse differs from electricity in several important respects. It travels too slowly, 100 feet per second being too slow for electricity. If a string is tied tightly around a nerve it will stop the passage of the nerve impulse, but such treatment of an electric wire will not stop an electric current over it. If

a nerve is cut and the ends put together ever so carefully, still no impulse will pass over the break. Cutting electric wires in no way impairs them; even though the ends be put together carelessly the current will pass along perfectly, if only there is good contact. Lastly, the nerve fibre is a poor conductor of electricity.

Taking all these facts together, it would seem that the nerve impulse is not exactly like any other kind of force with which we are acquainted. Although it certainly resembles electricity in many respects, at present it is regarded as a special kind of impulse that travels rapidly through the nerve fibre from any point where it may be started to the other end.

Nerve impulses may be instituted by many different methods. In the body they usually start from some part of a neuron, but we do not yet know the method by which this is brought about. Impulses may also be started artificially. If an electric shock is sent into a nerve, an impulse is excited and travels to the nerve ending; if the nerve is pinched or cut, an impulse starts from the point of injury. If a hot body touches the nerve, or certain chemicals are dropped upon it, these will also give rise to a nerve impulse. In some nerves an impulse is started by light, in others by sound etc.

## CARE OF THE BRAIN

Under the conditions of modern life to a far greater extent than in earlier centuries it has become necessary for each individual to use his brain. While some occupations require this more than others, there is none in which one is not helped in the achievement of success by having a well-trained and active brain. Education gives this training. As the years of school life pass, the brain not only obtains information, but it learns how to act; it grows stronger by use just as muscles do.

We sometimes hear of persons whose health has broken

down because of excessive mental work resulting in nervous strain. Since such a condition is very unfortunate and very serious, it is important to learn what causes contribute to it.

In the first place we may be confident that only in very rare cases is the trouble due to overwork, or to excessive study. The brain gains strength by use, and even a very hard student is not likely to use it too severely, if he is otherwise in proper health. If the brain is treated reasonably, and the whole body kept in a state of health, the brain may work very hard and grow stronger all the time. But the person who is fond of study is apt to neglect entirely the other functions of his body, and allow his muscles and other organs to lack proper exercise. Exercise, especially in fresh air to produce vigorous respiration, helps to keep the brain alert. The student perhaps fails to use proper discretion in his diet; overeating, irregular eating and too rich foods throw his body out of condition. The brain needs good wholesome food to keep it active, and it is well to remember that there are no special " brain foods," this term being used simply to catch trade for certain food products. The student neglecting some of these plain laws of health, becomes ill and his breakdown is apt to be considered due to over-study.

It is working the brain under improper conditions rather than working it too hard that produces nerve strain. Using the brain excessively without sufficient outdoor exercise, studying late at night when one needs sleep, using it too long upon the same kind of work, are all likely to injure it. *Rest and sleep* are necessary for an active brain. The amount of sleep needed is not the same for all persons, and growing people require more than adults. In general about eight hours sleep in a day should be taken by every one, and more than this by children. The attempt to study after one has become sleepy is always a mistake; in the first place it is the hardest tax on the brain, and in the second place it is often useless. The brain is not in condition to receive and remem-

ber, and it will be found the next day that almost nothing is retained of that which was studied the night before, so that the hard work was of no value. The bad habit of *cramming* should be particularly avoided. To accomplish the most in the way of learning, one should do a proper amount of work regularly each day. If this is done, it will be found that when the time comes for examinations, cramming will not be necessary. The poorest way to prepare for an examination is to sit up late the night before, vainly trying to crowd into a tired brain the information which should have been previously acquired. Too long continued attention given to one subject is also a mistake. A change of occupation is sometimes just as much of a rest as to stop work entirely. To work with the muscles is a rest from study, and reading is a rest from muscular work; to study algebra is also a rest from the study of language, although both of these require brain work.

The condition of the body is largely modified by the condition of the mind. We know, for example, that one's emotions affect the beating of the heart. Worry and anxiety are matters which have their origin in the mind; but their actual effect may take very unfortunate forms; e. g. loss of appetite, inability to sleep, super-sensitiveness, lack of interest in things in general. These and many other of our little ills are made worse by continually thinking of them. On the other hand, health is augmented by cheerfulness and mental buoyancy. Muscular fatigue, or even headache and toothache often disappear before a game of tennis or baseball, or during an evening of music. Digestive juices are more readily secreted when one is in good spirits, than when one is nervous or worrying. All of these things show that the mind has a decided effect upon the condition and general health of the body,—a fact which imposes upon one the possibility and duty of cheerfulness, not only because of the advantage to himself but for the sake of others.

## SYMPATHETIC SYSTEM OF NERVES

The term *sympathetic system* has been applied to a series of nerve cells and fibres which connect all the spinal nerves and, to a certain extent, bind them together, not only anatomically, but to a limited extent in their functional work also. Just how far there is any co-operation of this kind is uncertain, and the term "sympathetic," is not well applied.

This system comprises two strands of nerve tissue lying in the body cavity, one on each side of the back bone; Fig. 153. Each line of fibres makes connections with each of the spinal nerves on its side of the body, and at the junction with each spinal nerve a ganglionic collection of nerve cells is formed. Of course, no impulses really originate in the cords of the sympathetic system, but the fibres in them take up impulses which have come out over spinal nerves, from the spinal cord or from the brain.

The majority of branches from the sympathetic system go to the blood vessels in the abdominal region, and exercise constrictor effects on them. Some go to the heart, others branch and make an extensive network of fibres which here and there fuse together forming, with the addition of nerve cells, **ganglia.** Such ganglia are seen in the walls of the stomach, in the body cavity, in the " small of the back " and also in the neck, and from these ganglia, nerves pass out to near-by organs. The secretion of some of the large glands like the liver is controlled by impulses reaching them over the sympathetic fibres. As a rule, the impulses which pass through the sympathetic system are not under the control of the will, and furthermore they generally provoke responses from the organ to which they go of the very opposite character to that produced by impulses over the ordinary spinal or cranial nerves. For instance, the sympathetic nerves going to the heart carry messages that stimulate it to more rapid action,

while those going over the vagus nerves, direct from the brain, produce a slowing effect.

### DISEASES OF THE NERVOUS SYSTEM

If there is trouble in the brain it is liable to affect the whole life of the individual and especially his intelligence.

**Idiocy.**—Sometimes a person is born with the brain only partially developed, and even as he grows, it never becomes as large as it should. The skull, too, is usually small and peculiarly shaped. With an abnormally small brain there is sure to be found imperfect intelligence, and such a person is called an idiot. Idiocy is thus a lack of normal intelligence, due usually to the failure of the brain to reach its full size. Size alone may not determine the degree of intelligence in an individual. Frequently abnormal conditions in other organs (especially the thyroid) may produce defective mentality.

**Insanity.**—On the other hand, a person may have a well developed brain, but something may occur to interfere with its proper functioning. Sometimes, for example, an abscess grows inside the skull and presses on the brain; or after certain accidents, a bit of bone may press in upon it. In all such cases the mental powers of the person are thrown out of balance; he may imagine all sorts of strange things, e.g. that he is another person, or he may become violent and dangerous. Indeed, it is never possible to tell what he may do or think, and we call a person whose mind is so affected, insane. **Insanity** is very different from idiocy, for it is due to the derangement of brain functions which were originally normal. Insanity varies from a very mild type in which the person is perfectly sane on almost all subjects, but cannot think clearly on some one topic, to that in which the person is violent, and his thinking powers are completely upset.

Inasmuch as insanity is due, sometimes, to some pressure on the brain, it is occasionally possible to cure it by a surgical operation; in many cases, however, there is no cure. When a

person is born with the skull or some other part so improperly shaped, that the brain does not have the chance to develop rightly, a peculiar disposition may result. The person may be excessively irritable, he may be subject to fits, or quite lacking in any ideas of right and wrong, and thus apt to become a criminal. In some instances a slight operation has completely relieved these conditions, and a decided change in the person been produced.

**Paralysis, or Shock.**—The breaking of a blood vessel is one of the most serious accidents which may occur in the nervous system. It rarely happens in young people, although it occurs frequently in older ones. The breaking of a vessel usually produces a clot which may then press upon nerves and cause the trouble commonly called **nervous shock.** The kind of trouble produced, however, varies with the location of the clot. If this should be in the spinal cord, it may more or less completely cut off communication between the brain and the parts of the body below it. This of course would mean that both sensation and power of movement might be lost in these lower organs, i.e. the person would be paralyzed. If the clot is in the brain, and that organ is hindered in its functions, this also may produce paralysis. In **sensory paralysis,** only sensations are lost, the person can move the body but cannot feel; in **motor paralysis** he retains the power of sensation, but cannot move; in **complete paralysis,** both movement and sensation are wanting.

Recovery from this trouble is not very common. If it is due to a broken blood vessel and the clot is not too large, it may be dissolved and more or less completely disappear. If it is on the surface of the brain it may be removed by a surgical operation, but another break of the same kind is always apt to occur. Paralysis is an indication of the weakening of bodily vigor, and usually a sign of approaching old age.

**Nervous Prostration.**—**Nervous prostration** is the common

name for an affection of the nervous system, concerning the cause of which little is known. It sometimes occurs when one has been living for a long time under great nervous tension, such as comes from continued excitement, too little sleep or constant anxiety. It occurs more frequently in civilized life and the highly complex conditions of modern society than in the simpler life of the country. The symptoms of this trouble are too varied to be described here, but very often the person imagines himself ill from troubles which do not exist, and is in a constant state of worry about his own health. The remedy for nervous prostration is a complete change of life to relieve the body from the kind of strains which have been producing the trouble. If one lives simply, takes life as calmly as possible, does not allow himself to worry nor live too highly, he is well protected against this illness. Nervous prostration does not usually result from overwork, as has been frequently supposed. It is more likely to follow wrong habits as regards food, sleep, recreation etc. If one breaks the monotony of work occasionally with a brief period of real recreation, he may work very hard and long without serious consequences.

**Cerebro-spinal Meningitis.**—Meningitis is one of the very serious diseases, frequently fatal, and is caused by a certain bacterium which attacks the brain. It is more common among children than adults and sometimes occurs in epidemics. Its method of passing from individual to individual is not known, nor its means of entering the body. It is certainly not very contagious, rarely more than one case occurring in a family. Our lack of knowledge as to its method of distribution has prevented the devising of efficient rules for avoiding it, and the only suggestions now possible are to keep up the general health and to avoid contact with those suffering from the disease, and with secretions from their mouths. A method of combatting it by inoculation has been devised that is frequently successful in producing a cure.

## CHAPTER XX[1]

### A CLEAR MIND THE NEED OF THE DAY

Every living being must contend with enemies for its own existence. In the early periods man counted among his foes wild animals, storms, floods, famines and droughts. Against these he has in a large measure ceased to contend; he has overcome wild animals, and with fires, houses and various other devices can defend himself against the elements of nature. It is due to the wonderful power of his mind that he has been able to master these enemies, and it certainly behooves him to keep this, his greatest treasure, in as efficient condition as possible.

Man is still engaged in a struggle for existence with certain foes which his changed conditions have brought prominently forward, and the struggle is all the more severe because he does not always recognize his worst foes as foes at all. Among the most dangerous of his remaining enemies is the microscopic, parasitic germ. Doubtless, germs existed in the early periods of man's existence, but they were not especially serious until people came to live in crowded communities. The larger the community the greater becomes the danger from microbes. An epidemic may kill thousands and other diseases, like tuberculosis, which do not produce violent epidemics, are quietly at work destroying the lives of hundreds of thousands each year. Germs are particularly dangerous because they are invisible, because people do not know where they are nor how to avoid them, and because they are capable of multiplying so fast that no matter how many of them are destroyed, their numbers can in a few days be fully replaced

[1] This chapter is entirely the work of the senior author.

by the rapid multiplication of those which remain. Man is, however, learning to fight them more and more successfully. Microscopes are discovering where they are, and careful scientific studies are showing how in a measure they may be avoided. Indeed, through modern sanitation, which has driven them backward and has reduced the number and violence of epidemics, men have succeeded in making the city almost as secure against microbes as the country. We shall notice in another chapter some of the methods adopted today in fighting this worst enemy in our struggle for existence.

### THE USE OF DRUGS THAT AFFECT THE BRAIN

Another enemy against which man has to contend is especially dangerous because it also is not commonly recognized as a foe. Indeed, many people look upon it as a friend, while others regard it as a luxury, which may be indulged in more or less frequently without thought of danger. The nervous system controls the whole body, and everything that affects the activities of the brain has a profound influence upon the whole life. But some men have unfortunately developed the habit of using certain substances which have a direct action on that organ and interfere with its normal functions. There are two classes of brain drugs: **stimulants,** and **narcotics**—each of which has pernicious effects.

**Stimulants.**—There is great difference of opinion as to the proper definition of the word stimulant. This term usually, however, denotes a drug that will excite an organ to increased activity. The effect is temporary and does not indicate increased strength, but only enables the body to call upon its reserve power a little more quickly. In most cases, if not in all, the stimulating action is followed by a corresponding depression so that there is no gain in the end. A whip gives no power to a jaded horse, though it may excite him for a short time to more exertion. The constant use of a stimulant, too, acts somewhat like the constant use of a whip on a

horse; the animal soon ceases to mind the whip, or refuses to go without its constant application. The only substances in common use which act in this way are coffee and tea (caffein and thein). Persons who have become accustomed to these stimulants are no longer normal individuals, they cannot readily work without them and really suffer if deprived of them. Sometimes the effect of tea and coffee is so great as to cause positive ill health.

Strychnin, which is a deadly poison when taken in considerable quantity, will, when given in small amounts, quicken the heart beat. For this reason it has been prescribed by physicians in cases of critical illness where it is necessary to accelerate the action of the heart, and it has therefore been called a heart stimulant. The habit of using even mild stimulants like tea and coffee is, however, a useless and very unwise one for young people to acquire.

**Narcotics.**—Narcotics have an effect the reverse of that of stimulants. Instead of producing an increase of activity, they lessen it; instead of making the organs work more vigorously, they dull and render them less efficient. In particular they have the effect of causing the brain to become sluggish and finally of putting it to sleep. Just as fast as the brain comes under their influence, it loses its unique powers. The use of a narcotic thus deprives the individual of his most valuable possession.

The commonest narcotics are *opiates;* e.g. *laudanum, paregoric, morphine, soothing syrup. Cocaine, chloral, chloroform, ether* and the like also produce a deadening effect, though their action is different from the opium products. When one of these drugs has an action on the brain strong enough to cause unconsciousness, it is said to act as a **general anesthetic,** and if it produces insensibility to pain in only one particular part of the body without causing unconsciousness, it is called a **local anesthetic.**

Narcotics have their uses, and as a means of relieving pain

in emergencies they have been of incalculable benefit. But most of them have an unfortunate tendency to create an appetite, before which in the end the user becomes helpless. A person begins with a small dose, perhaps at the advice of a physician to relieve pain, and continues to repeat it either for the same purpose or for some other reason, until the habit of frequently using the narcotic is formed. The small doses cease to have the desired effect, the more it is used the more it is craved and the larger are the amounts taken. Surely and even rapidly this undermines the health and destroys the will power until the man becomes a wreck. Usually he does not appreciate the fact that he is coming under the influence of the drug until he becomes its slave, and when he does recognize that he is being ruined he is usually too far gone to wish to reform, or his will power is too much shattered to enable him to do so.

There are few more difficult habits to conquer than the opium habit and the only safe way to escape this great danger is by avoiding the use of this narcotic entirely. The same applies to the use of cocaine and chloral. The amount of injury done to children by the ignorant use of soothing syrups by their mothers or nurses cannot be calculated, and it is doubtless true that many a child's death is due to the use of such drugs, most of which contain opium or a similar narcotic. One should hesitate about the continued use of any drugs which rapidly relieve pain or induce sleep, though some are more injurious than others.

**Alcohol.**—The most commonly used drug belonging to the class of narcotics is alcohol. The dispute about the food value of alcohol has already been mentioned, but there is no question about classing alcohol as a drug which provokes the brain to abnormal action. If it is used constantly and in large amounts, it not only affects the brain but other organs. An inflammation in the form of chronic *catarrh* is produced in the stomach, and the functional activities of that organ are

decidedly impaired. In the liver a peculiar disease called *cirrhosis* sometimes appears, the liver becoming hardened and enlarged. The kidneys become enlarged by the formation of useless connective tissue which encroaches upon the kidney proper and weakens its action. The heart is sometimes enlarged and weakened. The blood vessels are permanently dilated, producing for example, the red nose which often marks those addicted to alcohol. Accompanying indulgence in some forms of alcoholic drinks there is a tendency to the formation of an abnormal amount of fat, which is only an incumbrance and tends to interfere with the normal functioning of certain organs. It is usually deposited in the abdomen but may be stored around the heart, tending to check its free action and produce heart troubles. All of these phenomena are abnormal, and indicate that alcohol deranges the body functions. Physicians recognize **alcoholism** as a very real and very serious disease brought on by the use of alcoholic drinks. When small amounts only are taken derangements are less evident, although the difference is probably in degree rather than in kind.

In all cases alcohol has some action on the brain, and the nervous system as a whole is the one most affected by it. Here its influence seems to be from the first that of a narcotic, since it always tends to dull the brain activities. One of its first effects is to stupefy the vaso-motor center. We have learned that this center governs circulation in general, always acting in such a way as to keep the small arteries partly closed, and thus regulating the amount of blood sent to different parts of the body. When this center is dulled the small arteries relax and the blood rushes through them faster than usual, the cheeks become flushed and the skin warmed; thus what appears to be an increased activity is really an effect of the narcotic action of alcohol on the brain. This increase of blood flow also affects the brain itself, causing a feeling of excitement, a certain hilarity of spirits which is

commonly mistaken for increased mental activity. Hence the stimulating effect of alcohol is only apparent and is really due to the partial paralyzing of the vaso-motor center.

The question whether alcohol is to be regarded as a narcotic or a stimulant has been very much debated, due partially to the difficulty of defining the word stimulant, and partly to the pseudo-stimulating action of alcohol. It is certainly true that many people have believed and still believe that it "gives strength." Indeed there is little doubt that many persons have learned to use it under a genuine conviction that it makes them stronger and even that it makes them think more quickly. But these beliefs are wholly unfounded. Alcohol does not give strength. At the risk of direct injury to many internal organs, it will furnish an extremely small amount of heat, although sugar and fat will do this much better. No one who understands the facts would ever use it when he has any hard work to do under the impression that it can under any conditions make him more efficient.

**Effects of Alcohol on the Brain.**—The most noticeable effect of alcohol is that upon the brain. Its use is followed by a feeling of excitement and flow of spirits that resembles very much the result of a stimulant. But this, too, is really due to the fact that its narcotic action has dulled the person's feeling of reserve and self control. He is apt to do anything that comes into his mind or say anything that impulse suggests, whereas ordinarily he would think further before speaking. Hence he speaks and laughs more easily, and in general acts as if stimulated, when the fact is that he has merely lost the valuable power of self restraint. The man who keeps his brain clear and uninfluenced by alcohol is usually more than a match for the one who has "stimulated" his mind by wine or other alcoholic drink.

The action of alcohol does not stop here, however. From the first it dulls the powers of perception and makes one less

quick to see and understand; one does less work or does it not so well, although oddly enough he thinks that he is doing better than usual. If more than a very small quantity of alcohol is used, its narcotic action becomes extremely apparent. Even before the person has any appreciation of the fact that the alcohol has influenced him at all, it has begun its effects. He becomes sleepy, loses control of his muscles, and staggers if he tries to walk; finally he may become totally intoxicated, in which condition his brain has become so completely paralyzed that it no longer has control over his body. In these extreme cases the narcotic action of alcohol is evident, but between the intoxication and the action of smaller amounts (as in the case of the moderate drinker), the differences are of degree rather than of kind.

One physiologist found after a dinner at which he had taken light wines, in amount not sufficient to have any appreciable effect upon him, that either his senses or his muscle control had become dulled, as shown by the fact that, if he went shooting at such a time, he always shot behind the birds, not being quick enough in his judgment or action to allow for their flight.

The German physicist, Helmholtz, found that if he had a difficult problem to think out, he must let alcohol *entirely alone*, for even the smallest quantity destroyed the keen edge of his thinking powers, and prevented him from doing his best.

Careful observations have shown further that in work requiring accuracy, e. g. adding figures or setting type, the use of a very small amount of any kind of alcoholic drink impairs a person's efficiency, making it impossible for him either to do so rapid or so exact work as usual. These illustrations are sufficient to show that even from the first the use of alcohol acts as a narcotic upon brain functions and that its apparent stimulating action is misleading, due to results which are the direct outcome of its narcotic action, e. g. dulling sensibility, relaxing the blood vessels and withdrawing self restraint.

Insurance companies have found by recent carefully collected statistics that, on the average, drinkers are shorter lived than abstainers. It is not surprising that these companies will not insure the lives of hard drinkers, but they have also found that the moderate drinker has a shorter life than the total abstainer.

The great business enterprises of this country have realized the sapping influence and dangerous tendencies of the use of alcohol. Of seven thousand industrial concerns questioned in this respect, 75% when engaging employees take into consideration the question of their use of alcoholic drinks. Over half refuse to employ persons in certain positions if they use alcohol. The large railroads exclude from places of responsibility those addicted to it, and banks will generally discharge an employee if they find him frequenting saloons. In short, a person is now seriously handicapped in getting a good start in life if he is accustomed to use alcohol in any form. He must frequently cease to strive for good, responsible positions and be content with those below the grade he could otherwise reach. Moreover, physicians in recent years are prescribing alcohol less and less as a medicine, many of them being convinced that its use for most purposes is futile. According to a report of the British Medical Society, with those persons over twenty-five years of age who use alcohol habitually, life is shortened on an average of about ten years, and the injury to the young is still greater.

"The best bred man indulging in wine with permissible moderation no more escapes the minor psychical changes induced by it than does the meaner slave fail of its sense-destroying power when he drinks till he remembers his misery no more. In the case of the former the mental changes induced will never attain the degree when self respect and social conduct are outraged, and they will pass unnoticed by all except those who are keen observers of their own mental states." (Abel)

It may seem a little strange to class disease germs and alcohol together as man's greatest foes, but it is really stranger that while we all agree to fight the one persistently, a considerable portion of mankind prefers to play with or indulge the other. Everyone who understands the nature of disease recognizes the need of fighting its agents or germs, but vast numbers of people welcome rather than struggle against the dangers of alcoholism. The reasons for this attitude are many, but one of them is that many fail to realize that the microscopic germs and the alcohol appetite are equally menaces to health and happiness.

Yet any one who will open his eyes to the conditions around him will see clearly enough that alcholism is, in the majority of cases, associated with disease, for the reason that it lowers one's powers of resistance. Besides shortening his own existence, the man who drinks much is living only part of his normal life, for his mind is constantly in a state of partial stupefaction brought on by the influence of this paralyzing drug. The old toper has lost the use of his most valuable possession, while the moderate drinker is endeavoring to meet life with slightly impaired mental capacity and physical powers. Many a youth begins with a little beer or wine in the desire to be "social," to do as others are doing, and inadvertently develops a habit which places him upon a lower plane of possibility and action than he would otherwise have attained. Probably there is no drunkard who, in youth, did not have his good intentions, his resolutions and ambitions to be and to do good, but he trifled with them. It is never possible to predict whether or not one will become a victim of this appetite, for persons with apparently the strongest wills are often those who yield most readily. The desire for alcohol is an insidious one which grows slowly, usually without the consciousness of the individual, until it becomes too strong for him or until he ceases to care whether he masters it or not. Whole families are wiped out by the evils which come from

its use, and hundreds of thousands of individuals are deprived of one or more years of useful and enjoyable life by imprisonment for crime committed while under the influence of alcohol.

There are other foes with which we have to contend in our efforts to make life a success, but none is greater than these two. The person who does achieve success, both in his outer and in his inner life, is the one who learns to keep his body in health and his mind clear. The intellect is man's most precious possession, and in weakening it, alcohol is attacking him at the very point on which he must place his dependence if he is to carry on a successful "struggle for existence."

**Tobacco.**—The formation of the tobacco habit also presents a question difficult for some young people to settle. The action of tobacco upon the body is a more or less complicated one, and is not the same in all individuals. Tobacco contains a poison, *nicotine*, which has a powerful influence on nerve cells.

The physical effect of the use of tobacco depends upon the quantity used, and, as we have just said, upon the individual user. If very small amounts are used it is doubtful whether there is an appreciable result, and the injury may not be recognized. Whatever influence it does have is bad, especially for young people. If large quantities are consumed, the effect is frequently noticeable in an abnormal heart action and in the stupefying of the brain. The "tobacco heart," the "cigarette heart," have become well known terms which the physician applies to certain symptoms due to the extensive use of tobacco.

The effect of tobacco upon those who have not attained their full growth is probably always injurious. The evidence is complete that its use by such persons prevents the full and proper development of the body, and that a boy who smokes constantly is stunted in his growth. In intellectual power, too, young people seem to be injured by the tobacco habit.

A careful study of the records made by college students shows that those who habitually use tobacco are, on the average, mentally inferior to those who do not have that habit. The brightest and most independent are most likely to avoid it. After one reaches maturity, i. e. after twenty-five years or so, the effect of tobacco smoking is not so noticeable, but for all persons of student age the habit is very unwise, and sometimes disastrous. Moreover, employers of boys find the cigarette smoker decidedly inferior to his cleaner companions, and this inferiority, generally speaking, may be said to persist in later life. The smoker is often incapacitated for fine work.

## MEDICINES

In spite of all one's attempts to keep himself in proper health, he does not always succeed, and almost everyone is occasionally ill. There is a very general feeling that if one is ill the necessary thing is to take a dose of medicine. People have a notion that medicine in some mysterious way will cure disease no matter what its cause, and sometimes no matter what the medicine. Much evil results from this ignorant idea. For ordinary ills there is always a cause, and the proper course is to *remove the cause rather than to take medicine.* If, for example, one suffers from indigestion, he should endeavor to change his food habits or his food, or to take more exercise rather than to continue in the old way and rely upon medicine to cure. Indeed, most of the little ills in life can be readily mastered by a change of habit, without medicine. Medicine has its uses, beyond doubt, but it is very unwise and unsafe for the untrained person to administer it.

Especially is it a mistake to buy and use the numerous so-called "*patent medicines,*" extensively advertised and claiming to cure a long list of troubles. This does not mean that none of them has any value, but that many contain powerful drugs, alcohol or opium, which cannot be safely used by anyone and certainly not without the advice of a

physician. Beyond a few simple remedies we should leave the giving of medicines to a physician who understands that they are merely a help and not a cure for disease and that the patient is frequently better off without them.

If one recovers from disease it is often because the body cures itself by its own vitality. Medicines may assist, but a person really cures himself. The taking of too much medicine without the advice of a physician is one of the great faults of the American people. Every young person in preparation for life should make up his mind that, if properly treated, his body can take care of itself without the use of drugs. If it is ill, except when the trouble is a germ disease, the difficulty usually lies in an improper mode of living, and this cannot be cured by medicine. Medicines, properly administered by one who understands them, are useful, but miscellaneously used by others, they are productive of a vast deal of harm and an incalculable waste of money.

## CHAPTER XXI

## ORGANS OF SPECIAL SENSE—THE EYE

In a preceding chapter we noted that every sensory nerve ends in a special bulb, or corpuscle, and some of these were shown in Figures 117, 118 and 162. The endings there represented were very simple, having only simple functions to perform, like that of receiving touch, heat or pain stimuli. There are other sensory nerves, particularly some of those coming out of the brain directly, which have very elaborate endings, usually spoken of as organs of special sense. The most important of these are the **eye** and the **ear.**

### EXTERNAL PARTS OF THE EYE

The eye (Fig. 165) is set into a cavity in the skull, the **eye socket,** which is lined with a layer of fatty tissue serving as a cushion. The eyeball is not perfectly round, since over the colored portion at the front the sphere bulges slightly, although not enough to be noticed ordinarily.

Externally the eyes are protected by the **lids,** which are folds of the skin of the face supplied with muscles to permit movement in winking; Fig. 166. In the process of moving the lids two muscles especially are concerned: one, the so-called **orbicular,** is a circular muscle running around in both the upper and the lower lids; the other, the **levator,** is in the upper lid, and runs upward from the edge and raises it after the orbicular has closed the eye. The lower lid moves very little, and is not drawn downward by any special muscle.

At the inner corner of each eye is a little whitish mass of tissue which is of doubtful value in man; in birds and some reptiles, a corresponding structure is a third eyelid, which is transparent and can be closed while the others remain motionless.

The **lashes** on the edges of the lids protect the eyes somewhat from dust. The inner surface of the lids is really nothing but the external skin folded back underneath, but it is provided with special glands which are not present in the ordinary surface of the skin. These **Meibomian glands** are arranged in little clusters, with their openings near the edges of the lids (Fig. 166) and are more abundant in the upper than in the lower lid. Their secretion is oily and by mixing with the more watery product of the tear glands prevents the rapid drying of the latter as it is spread over the eye in a thin layer when one winks.

A tear, or **lachrymal,** gland is located just above the outer corner of each eye. It is about three-quarters of an inch long, one-quarter of an inch wide, and the material which it secretes is poured under the upper lid through six or seven tiny canals. This **lachrymal secretion** is largely water, with a little salt, and the smearing of the secretion over the eyeballs in winking prevents the delicate membranes of the eye from becoming dry, and consequently more or less opaque.

The liquid material secreted by the several glands about the eye runs away through two tiny openings in the inner corner of each eye into canals, which unite into the **lachrymal duct,** leading to the nose chamber. A downward current is produced in these canals by cilia which project into them on all sides.

**Muscles which Move the Eye.**—The movement of the eye is effected by six different muscles, all of which are attached to the eyeball at different points back of the lids: Fig, 165. Four of these, one above, one below, one outside and one inside, are called **rectus muscles** and pass from their attachments to the eyeball directly back to a point in the deepest part of the socket. The one next the nose is called the internal rectus; the outer, the external rectus; the upper is the superior, and the lower the inferior rectus. The other two muscles are called the **obliques.** The inferior oblique is attached to the lower sur-

face of the eyeball and to the bones on the side of the nose. The superior oblique muscle on the upper surface of the eye passes inward toward the nose, but on reaching it, its tendon

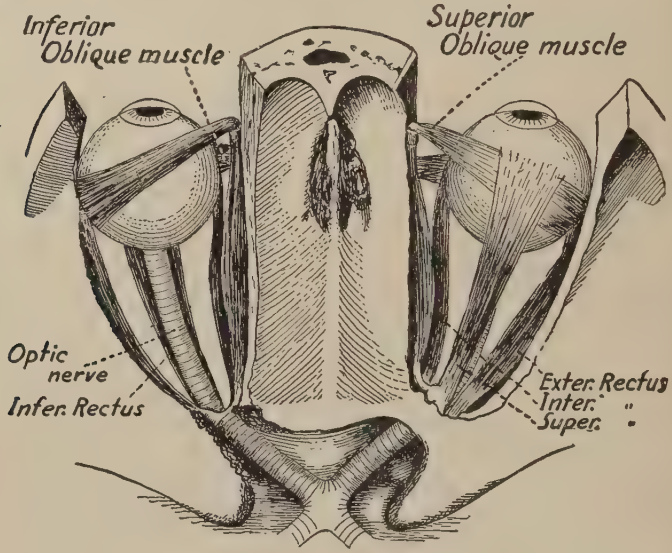



FIG. 165.—DIAGRAM

Showing the eyes in position in their sockets, the muscles that move them and the optic nerves. (Fox)

goes through a loop, which acts as a pulley, and then passing backward is attached near the same place as the rectus muscles.

DEMONSTRATION.—The muscles which move the eye can be well shown by use of the eye of a dog-fish. The skull is cartilaginous and easily cut away, and the muscles are diagrammatically plain. Appendix, Section 30.

All movements either in a vertical or a horizontal plane must be made by the rectus muscles, and movements not exactly in either of these planes may be produced by the combined action of two or more of them. It would seem that their contraction would produce all movements the eyes ever make. As a matter of fact, however, the oblique muscles are

constantly used, not alone, but to adjust the movements of the rectus muscles more accurately.

The extreme delicacy with which these muscles work is not usually appreciated. Especially remarkable is the accuracy with which they move when one is reading a printed page. The eye is perfectly directed to a certain letter, to comma or period, and then as suddenly turned, it may be only a hair's breadth, and the process repeated thousands of times in an hour, yet always with the most remarkable precision.

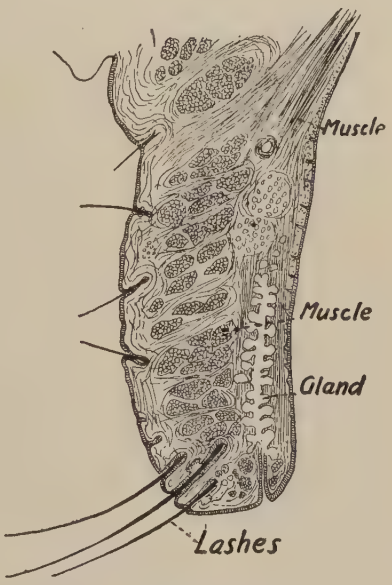



FIG. 166.—A SECTION THROUGH THE UPPER EYELID
Highly magnified. (Fuchs)

## STRUCTURE OF THE EYE PROPER

**The Sclerotic and Choroid Coats.**—On the exterior of the front of the eye is an extremely thin layer of tissue called the **conjunctiva.** This is continuous with the lining of the eyelids, and its transparency makes it imperceptible. Beneath the conjunctiva is a thicker layer which extends over the whole eyeball, serving to protect it and keep it in shape. In front, this also is perfectly transparent; but beginning with the "white" and passing about the rest of the sphere, it is tough and opaque. The transparent portion in front is called the **cornea,** the rest the **sclerotic coat**; Fig. 167.

Beneath the sclerotic and cornea is the **choroid coat;** Fig. 167. It contains a large number of blood vessels and is the principal nourishing layer of the eye. The choroid covers the whole ball save a small spot exactly in front, the **pupil.** Around the pupil is a colored area, blue, brown or black, as the case may be, called the **iris.** The pigment area of the iris is for the purpose of shutting out all light except an amount sufficient to stimulate properly the nerves of sight. When the light is dim, more must be admitted to produce the requisite degree of stimulation; consequently the iris is provided with muscles by whose contraction and relaxation the aperture of the pupil is made smaller or larger. Certain other muscles belonging to the choroid coat will be mentioned in a later paragraph in connection with the focusing mechanism of the eyes.

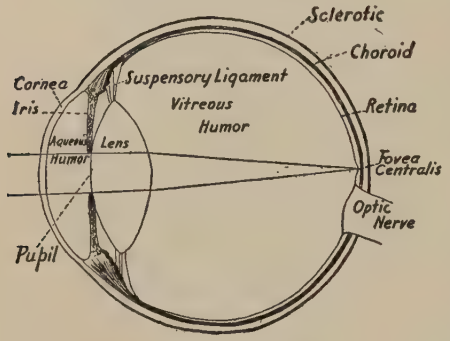



FIG. 167.—DIAGRAM
Showing a section through the eyeball

**The Retina.**—Inside the choroid covering is the **retina,** the only layer of tissue in the eye which is sensitive to light. This does not go entirely about the eye, being absent in front in the region of the iris and pupil.

**The Vitreous and Aqueous Humors.**—Filling up the center of the eye, and making the whole organ spherical, is a mass of clear, jelly-like material, the **vitreous humor.** In front in the space between the iris and the cornea is also a mass of clear, transparent material, the **aqueous humor,** which causes the cornea to protrude slightly; Fig. 167.

**The Lens.**—The lens also is made of perfectly clear, transparent material of the consistency of thick jelly. In shape it

is like ordinary glass lenses, though more convex on both sides. If taken out of the eye, the lens still has enough rigidity of its own to keep its shape. It is in the same cavity with the vitreous humor in a vertical plane just back of the iris. Note in Figure 167 that the lens is more convex on the back than on the front side, and that at its edges it is held in place by slender ligaments which run outward into the choroid layer. These are collectively called the **suspensory ligament,** which must be thought of as a thin sheet of ligamentous tissue going entirely about the lens border, rather than as a cord attached to any one or several points. It swings the lens into position, by tension on its edges in every direction.

### THE FORMATION OF IMAGES

When one's eyes are open, there is formed upon the retina a picture or image of the object in front of the eye. The secret of this picture formation lies entirely in the lens and the cornea, more especially in the former.

Everyone knows that light, reflected from trees, buildings, people or other objects, on passing through the lens of a photographer's camera produces an impression on the sensitive plate within. If we compare this plate to the retina of the eye, and the lens to the lens of the eye, the similarity between the eye and the camera is very striking. In Figure 167 is shown the arrangement of the lens and the retina. Straight lines show the direction which rays of light take in the eye. In this case it is supposed that the object seen is a point and that the rays of light entering the eye are parallel. It will be seen that these rays after passing through the lens bend from their parallel direction and come together. It is plain that they must meet, otherwise they would strike many different parts of the retina at the same time, and a large number of points instead of one would be seen. Each would be seen indistinctly, too, since the light would be so subdivided as not to be intense at any one place on the retina.

The law which makes the rays bend as they go through the lens, and causes them to form an image on the other side is very simple. When a ray of light passes from any point through air, it always passes in a straight line; but if it enters a transparent substance like glass, which is denser than air, it is usually turned to one side. If it enters the glass perpendicularly, it still goes on in a straight line (Fig. 168 *C-c*); but if it enters at an angle it is always bent to one side, and the greater the angle at which it enters the more it is bent (Fig. 168 *A-a*, *B-b*). After it has passed through the glass and as it comes out on the other side, it is bent again.

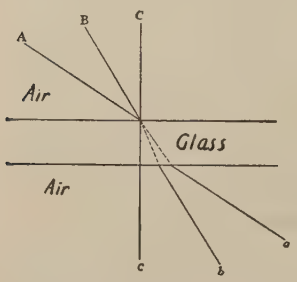



FIG. 168.—DIAGRAM
Showing the refraction of light while passing through a piece of glass with parallel surfaces.

So it happens that rays of light in passing through glass at an acute angle to its surface are sure to change their direction. One often sees this principle illustrated when he looks out of doors through a window. If the light from the objects thus seen comes to him through a more or less irregular piece of ordinary window glass, and especially if it comes through slantwise, the object seems to be very much distorted. If one sees things through a piece of plate glass there appears to be far less disturbance of the image than in the case of uneven glass, yet when the plate glass is bevelled along the edge, objects which can be seen through the general surface plainly, cannot be seen at all, or only in a distorted manner through the bevelled area. Light from the object in going through the bevelled surface has been thrown out of its path.

Let us now notice the effect of a lens upon rays of light.[1] The surfaces of the lens are curved, i. e. parts of spheres. From Figure 169 it will be seen that if parallel rays enter the

[1] For demonstration see Appendix, Sections 32 and 33.

lens, they enter it at different angles, and are consequently bent in different directions and that when they emerge they are bent again, each differently from the others. Now when the surfaces of the spheres are perfect curves, the angles at which the rays enter and leave it are such that after passing through they are bent toward one point where all of the rays meet; Fig. 169. If a sheet of paper is held at this **focus**, a point of light will show upon it.

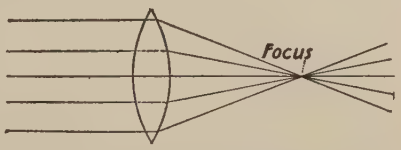



FIG. 169.—DIAGRAM
Showing the manner in which a lens bends rays of light so as to bring them to a focus.

Figure 170 shows a slightly different condition. Here *A* is a point of light near the lens, and from it light rays pass outward in all directions. The rays are not parallel as in the former instance but diverging; yet they are bent as before, as they are passing through the lens and are also brought toward one point *a*, at which they focus. But it will be noticed that this focus is farther from the lens than the

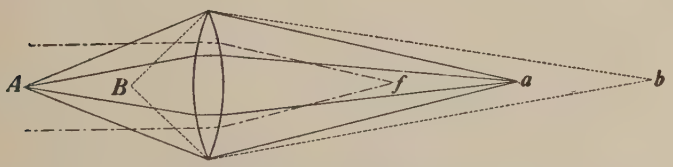



FIG. 170.—DIAGRAM
Showing the relative position of the foci formed by parallel rays of light and by diverging rays of light coming from objects near the lens.

focus of parallel rays, *f*. If the point of light is brought nearer the lens, at *B*, its focus, *b*, will be still farther away.

There is a way in which the image can be brought nearer to the lens and the focal distance not be lengthened. If the lens be replaced by one of *greater curvature*, i. e. more bulging, it will bring the rays to a focus sooner. If on the other

hand it is replaced by one of *less curvature,* it will bend them less sharply and bring them to a focus at a greater distance from the lens. If, however, the lens be *concave,* the rays will be scattered instead of being brought to a focus. It is important that these points be clearly seen, in order that one may understand the accommodation of the eye.

If, instead of a single point giving out light, there is an object of some size, the action of the lens is essentially the same. Suppose that the object is a candle flame (Fig. 171); the tip of the light, *A*, is a point and the rays passing from it will, of course, be focused at a point, *a*. The base of the light is another point, *B*, which will be focused at *b*. In the center of the candle we might select another point which would then be focused between *a* and *b*. The whole candle and its flame are made up of points, each of which will be focused at a corresponding point. If, therefore, a piece of paper or a screen be placed at the line, *a-b*, we shall find an image of the candle flame upon it. The image, however, will be upside down, as is evident from the figure.

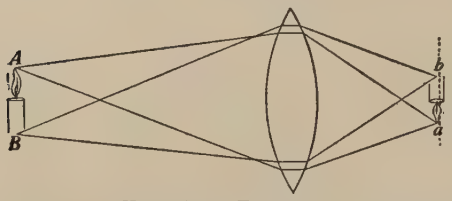



FIG. 171.—DIAGRAM
Showing the method of the formation of an image by a lens.

In the human eye an image is formed in exactly the same manner. The lens focuses the light that passes through it and produces an image at a certain distance behind it. In a normal eye the retina is at just the proper distance so that the rays of light are focused upon it, and the image thus formed; Fig. 172. Since this image is, of course, up side down, one naturally asks, why do we not see things in inverted positions. This question arises from the false impression that one's brain pictures things just as they occur on

the retina, as if the brain were looking at the image on the retina. The exact process by which the brain perceives the image is complicated, and not entirely known. For our purpose it is sufficient to say that although the image is certainly inverted on the retina, after the impression has reached the brain, it is interpreted so that we see things as they are.

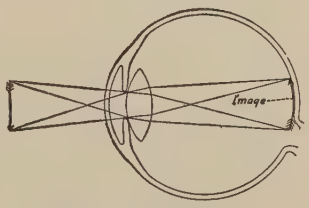



FIG. 172.—DIAGRAM
Showing the formation of an image upon the retina.

**Accommodation.**—Every one knows that it is perfectly possible to look at a spot on the window glass and see it clearly, and at the same time see indistinctly whatever there may be beyond the glass, trees, buildings etc. If one chooses he can give all his attention to the trees and see them very clearly, at the same time seeing very

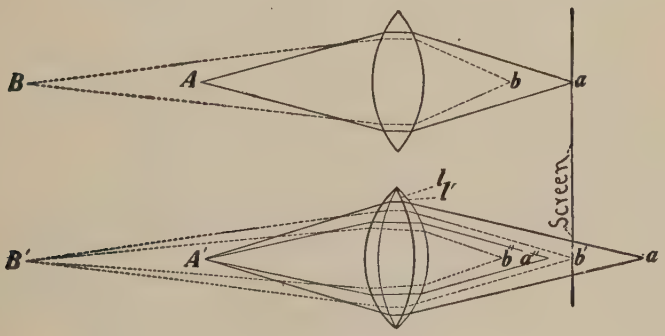



FIG. 173.—DIAGRAM
Showing the effect of different lenses in changing the position of the focus of light and illustrating how a change of the lens is necessary if objects at different distances are to be focused upon a screen.

indistinctly the window glass and frame. When he changes his attention from one to the other he is conscious that something is taking place in his eyes, and that it requires part of

a second, at least, for the change to be made. This process is called **accommodation,** and occurs almost entirely in the lens, although the front of the cornea is also slightly modified.

The form which a lens must take when the object viewed is near at hand, as compared with its form when the object is far away, is shown in Figure 173. When a point is near the lens, as at $A$, the rays of light going from it will diverge rapidly. In order to bring them to a focus at the distance of the screen or retina, they must be bent very decidedly inward. It is also evident that if a point is farther away from the lens, as at $B$, the rays will not be diverging as rapidly when they reach the lens, and not being turned from their course as much as those from $A$, will come to a focal point in front of the screen or retina at $b$. Moreover, we have already noticed that the more bulging or convex the lens, the more sharply the light rays going through it will be bent from their paths. If, therefore, a flatter lens is substituted, like the one marked $l$, which has a curvature only sufficient to bring rays from point $B'$ to a focus at $b'$, the rays from point $A'$ will not be sufficiently bent and will be focused behind the screen at $a'$. But if a more convex lens is substituted, like the one at $l'$, the rays from both $A'$ and $B'$ will be focused in front of the screen at $a''$ and $b''$. Thus a lens of a definite curvature is necessary for properly focusing light from any particular point. If one wishes to look at a distant point after examining a near one, the lens must be flattened; and when the attention is turned from a distant point to a near one, a more convex lens is necessary.

**Mechanism of Accommodation.**—In the eye it is not necessary to replace one lens with another, for the lens of the eye is not rigid like glass, but can change its shape from a thin, flattish to a very convex form. Attached to the edge of the lens and holding it to the choroid layer, we have noticed the suspensory ligament. This is under tension, and as a result

is pulling outwards on the edge of the lens in every direction; Fig. 167. Since the lens is somewhat soft, this outward pull tends to flatten it. In this shape, the lens is in condition for focusing on the retina rays of light coming from a distance.

If the object viewed is near, as it is in reading or writing, the lens must be more convex. All that is needed to make it so is to loosen the ligament, when the lens of its own elasticity will bulge, and assume the necessary convexity. For every different distance the tension of the ligament must be changed accurately and almost instantaneously, so that the convexity of the lens may be exactly correct. This regulation of the suspensory ligament is accomplished by the so-called **ciliary muscle,** (Fig. 174), one end of which is attached to the choroid coat behind the point where the suspensory ligament arises, the other end fusing with the iris and the inner layers of the cornea. When this muscle contracts, it is easy to see that the choroid layer will be pulled forward, the ligament will become loose and the lens will "bulge," taking the shape of the dotted line in Figure 174. The more the muscle contracts, the more convex the lens will become, and consequently the nearer objects may be held and yet be seen. There is, however, a limit to the nearness at which objects may be seen. The ciliary muscles can contract only a certain amount, and the lens can become convex only within certain limits. When an object is held too near the eyes, everything becomes blurred since its light is not focused on the retina. The chief reason that one's eyes become tired from reading is that the ciliary muscles are weary from staying contracted during the pro-

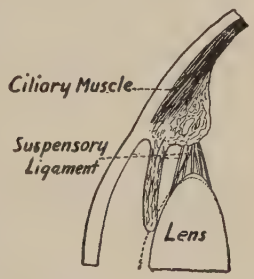



FIG. 174.—DIAGRAM Showing the method by which the lens is held by the suspensory ligament, and the ciliary muscle whose contraction will loosen the ligament and allow the lens to bulge.

longed period that one has been looking at the book held near the eyes.

Figures 175 and 176 show what the result would be if the lens of the eye could not be accommodated to different distances. There would be only one point at which objects could be seen clearly. If parallel rays of light are focused on the retina as in Figure 175, rays from points near by, as at *A*, will be focused behind it. If, however, rays from an object near the eye are properly focused, as in Figure 176, objects farther away would be indistinct because light from them would come to a focus in front of the retina. The power of changing the shape of the lens allows objects at any distance (not too near) to be seen clearly.

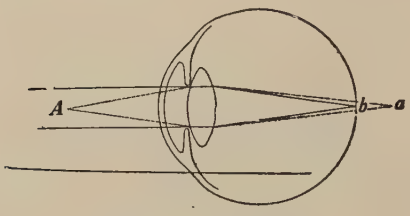



FIG. 175.—DIAGRAM
Showing that when parallel rays of light are focused on the retina, rays from near objects will be focused back of the retina.

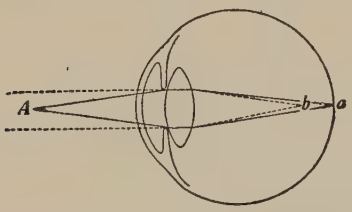



FIG. 176.—DIAGRAM
Showing that when near objects are focused on the retina, parallel rays of light will be focused in front of it.

**Near- and Farsightedness.**—The normal eye is of such shape that parallel rays of light are focused exactly on the retina; Fig. 175. Often, however, a person's eyeballs are a little too long or the lenses a little too convex (Fig. 176), so that entering rays of light coming from a distance are not focused on the retina but in front of it, and to be focused exactly on the retina, an object must be held close to the eyes. **Nearsightedness,** or **myopia,** may result from either of these causes, and in either case the difficulty may be remedied by

glasses. The reason that the nearsighted person finds it hard to see distant objects distinctly is that the rays forming the image come to a focus too quickly after entering the eye; if lenses of just the right curvature be placed in front of his eyes, so that the rays are caused to diverge a little before reaching the eyes (Fig. 177, dotted lines), the rays will be brought to a focus at exactly the right place. By "fitting a person with glasses" we simply mean that extra lenses are chosen of just the right curvature to correct his particular trouble. Myopia is common among those who read very much or use their eyes for other work at close range. To avoid developing nearsightedness, one should acquire the habit of holding books at least eighteen inches from the eyes.

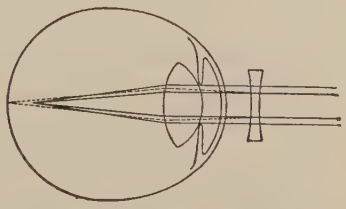


FIG. 177.—DIAGRAM
Showing a nearsighted eye with a proper lens for correcting the defect.

In **farsightedness**, or **hyperopia**, the conditions are just the reverse of those in nearsightedness. The person cannot see a near-by object clearly because the lens is too flat or the eyeball too short. The rays of light going into the eye come together behind the retina, as shown in Figure 178. In such an eye even the full contraction of the ciliary muscle may be unable to make the lens convex enough to bend the light rays to a point by the time they reach the retina, and consequently the image is blurred. If, however, a slightly convex spectacle lens be used, which will turn the rays and start them to a point, the lens of the eye can do the rest; Fig. 178.

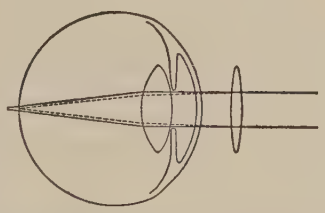


FIG. 178.—DIAGRAM
Showing a farsighted eye with proper correcting lens.

**Astigmatism.**—We have assumed that the surface of the cornea in front and of the lens behind it were parts of true spheres, curving equally in all directions. The majority of eyes, however, are **astigmatic,** i. e. there is somewhere, either in the cornea or lens, an irregularity so that the combined shape of these bodies is more like that of a football than like a true sphere, curving in a circle in one direction, but in an oval in the other. As a rule there is one plane in which persons with astigmatic eyes can see well, but in all other planes the image will be blurred; Fig. 179. To remedy this very serious defect it is plain that neither a perfectly convex nor a perfectly concave lens will suffice. The need, then, is for a lens ground at two different curvatures, the opposites of those in the eye lens.

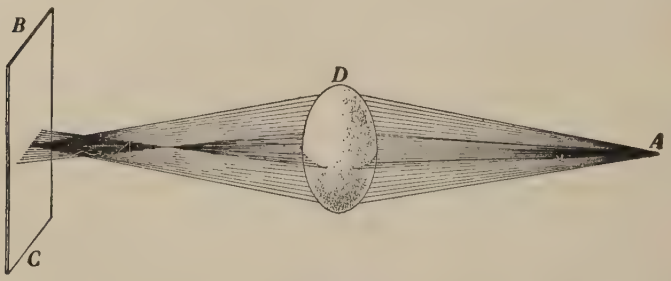



FIG. 179.—DIAGRAM OF DEFECTS IN AN ASTIGMATIC EYE

Showing that rays from a point are not properly focused. A, source of light; B, C, retinal surface; D, lens. Rays in one plane come to a focus at a point; in the other plane they are distributed over B C in a line.

## THE RETINA AND ITS FUNCTIONS

We have seen that the images of objects in the external world are focused upon the retina, a fact which suggests that this is the sensitive, i. e. the real seeing part of the eye.

The actual thickness of the retina at its thickest part, at the back, is only about one seventy-fifth of an inch and it is much thinner than that on the sides of the eye. Its border

near the sides of the iris is a mere frayed edge of tissue. Yet this thin layer is a very complicated structure, a microscopic section showing eight well defined layers or strata. Next to the choroid coat is a **pigment layer.** At first glance this usually appears black, but when more carefully examined it proves to be made up of granules of a purplish hue, a fact which explains why this material is sometimes called the "**visual purple.**" This pigment is not laid down in an even coating next the choroid, but is arranged in a kind of mosaic of six-sided patches.

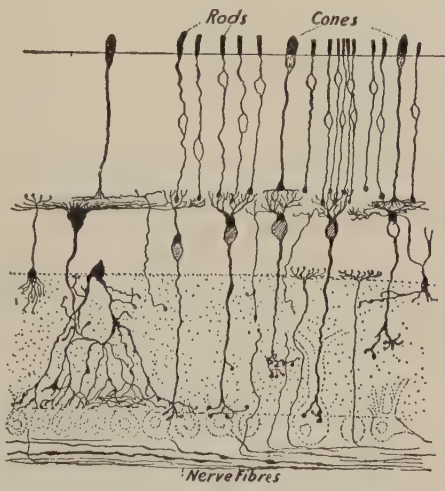



FIG. 180.—SECTION THROUGH THE RETINA Very highly magnified. The lower edge is the one toward the center of the eye. The rods and cones are indirectly connected with the nerves. (Cajal)

Next the pigment is a layer of cells of very peculiar shape. Each contains a nucleus like any other cell, but has two outgrowths on opposite sides; Fig. 180. On one side a fibre extends and ends in numerous small branches or arborations; on the other side opposite the fibre, in some a rod-like, in others a cone-like structure is found. These **rods and cones** are all arranged parallel with one another, their ends pointed toward the pigment layer, the rods in many cases reaching into the pigment. At the back of the eye the cones are much more abundant than on the sides of the eyeball, where the rods predominate. In the very center of the back of the eye directly behind the pupil, is a minute area in which there are

only cones, and which lacks nearly all the other layers of the retina. It is plain from its situation that light coming directly into the eye falls on this spot. This is the area of clearest vision, or in scientific terms, the **fovea centralis**, Fig. 167.

The other layers of the retina are represented in Figure 180, but no special description of them will be given. From the figure it will be noticed that from the inner ends of the rod and cone cells other nerve cells arise, which extend toward the inner portion of the retina, and are there connected or closely associated with nerve fibres. Any impulse, then, which starts from the rods and cones may pass up through these connections until it reaches the nerve fibres, and goes through them to the brain.

The nerve fibres thus arise on the innermost side of the retina next to the vitreous humor. They all pass toward the back of the eyeball and finally unite to form the large **optic nerve.** This nerve passes through the various coats of the eyeball and then goes to the brain. It does not leave the eye directly at the back, in the line of entering light, but on the side of the eye toward the nose. At the point where the nerve leaves the eye there is a small area which, having no rods or cones and no pigment (these structures alone are really sensitive to light), is blind and is therefore called the **blind spot.** In the ordinary use of the eyes, however, we do not notice the presence of any such area.

### EFFECT OF LIGHT IN THE EYE

How does light act on the parts of the eye which are sensitive to it—the pigment and the rod and cone layers of the retina? No one has any precise knowledge of this matter, but there are two interesting theories as to its effect.

**The Chemical Theory.**—The chemical theory supposes that the chemical composition of the pigment layer is changed by light, somewhat as is the sensitive plate in a camera when the shutter is opened. The theory rests upon these facts:

(1) that the amount of pigment increases when the eye is closed, and decreases when light enters it; (2) that if the eye of an animal be closed, the animal then immediately killed and the eye first opened in a solution of alum in a dark room, the image of the last thing seen by the eye can thus be preserved in the pigment layer. (Such a picture is called an **optogram**). A difficulty in the way of accepting this theory is that it supposes the pigment to be constantly broken down by light and again restored. In reading, for example, the shapes of thousands of letters and the spaces between them and between the lines are continually appearing and forming rapidly changing pictures on the retina. In the ordinary use of the eyes, hundreds of different images are being formed and changed every minute. In order to be continually in condition to receive new light rays, i.e. receive new images, the pigment would have to undergo repairs at a rate of which we can hardly conceive.

**The Mechanical Theory.**—The mechanical theory supposes that light falling on the retina disturbs or shakes the rods and cones, and thus starts in them impulses which travel through their connections to the optic nerve and thence go to the brain. How can this be possible? In answering this question we have to remember that light itself is in the form of very short, wave-like movements. The rapidity of these vibrations is almost beyond our powers of appreciation; but the theory is that they pass into the eye and thus stir the rods and cones to the same rapid movement, the disturbance being interpreted in the brain as "light."

The main reason for doubting that the effect of light in the eye is so simple is that the light waves take place at such very rapid rates. For instance, the slowest movements which we interpret as light at all occur at the rate of 107,000,000,000,000 per second; the fastest rate which we can perceive at all is 40,000,000,000,000,000 per second. Red light vibrates at 392,000,000,000,000, and violet at 757,000,000,000,000 per

second; the other colors which we can see are caused by vibrations at rates between those of red and violet. Although these figures really mean very little to us, it is certainly improbable that the material particles which we call rods and cones can be thrown into such rapid movement, and especially hard is it to see how their rates of vibration could be changed from one frequency to another with such accuracy as they must be when one suddenly looks from red to violet, or from yellow to green, for example.

In spite of the reasons which make it seem hard to believe the action of light on the retina of the eye to be either chemical or mechanical, we can hardly avoid the conclusion that it must be one of these two, or a combination of them. We are practically forced to say that we do not know what light really does in the eye.

## COLOR VISION AND COLOR BLINDNESS

We have already noted that in the back of the eye cones are especially abundant and diminish toward the sides of the retinal area, while rods are few at the back and plenty on the sides. Hence light entering the eye from the side would strike mainly on rods, while that going straight toward the back would disturb chiefly cones. If we keep this fact in mind, and reflect that the color of an object is most plainly seen when the object is straight in front of us, we must conclude that the cones are the more sensitive of the two to color changes. Rods seem to be sensitive to light and shade, but not to color, while cones are sensitive to both. It can be proved by experiment, too, that a larger area of the retina is sensitive to one color than to another; for example, one can see violet objects as they are brought around slowly from the side to the front sooner than he can identify a green object so brought before him. Consequently we conclude that the area of the eye which can see violet is larger than that which can perceive green. The area which can see red is also larger than

that which is sensitive to green, but smaller than that which is sensitive to violet. Physiologists claim that red, green and violet are the only colors perceived by the eye, and that other colors are seen when two or more of these colors are stimulated at the same time, in different degrees.

**Color blindness** is a more common defect than is supposed. It consists in inability to see any difference between two colors which seem to most people very unlike and distinct. The most common kind is that in which a person is unable to distinguish between red and green. To such a person the only difference between red apples and green leaves on the same tree would be merely a difference in shape and brightness. If one accepts the theory that the eye perceives only red, green and violet, then red color blindness would be explained by supposing that the red sensations were only imperfectly developed, or perhaps altogether lacking.

Persons who are color blind cannot obtain employment on railroads or ships, for in such positions it is absolutely necessary that one see clearly both red and green, since flags, lights etc., used as signals are generally of these colors. There is no known remedy for this defect.

## CARE OF THE EYES

Probably no defects are so apt to escape attention and proper treatment as imperfections in the eyes. Even in cases where the eye is very defective, one may see fairly well and so neglect to attend to the matter. The result is that some part of the eye may be in a condition of strain, trying to force the refractive surfaces into shape to produce a proper focus upon the retina. This strain brings on fatigue of the delicate muscles themselves and exhaustion of the nerves that may lead to serious results, e. g. headaches, indigestion, nausea and various nervous diseases. Any one of these outcomes is sufficient practically to disable a person for hard work and to cloud living with continuous pain. The mental

and physical disturbances which follow in the wake of eye defects should lead one to the most jealous care of these priceless organs. Glasses should be fitted by a skillful oculist as soon as it is discovered that the eyes are unable easily to meet the demands upon them. The cost of this sort of care should not be allowed to influence one in the matter of procuring and following the most expert advice.

If one has to hold a book nearer to the eye than 12 inches, the indication is that he is nearsighted. On the other hand, if he finds it necessary to hold a book 20 inches or more from the eyes to read it easily, the probability is that he is farsighted. In either case he should consult an occulist.

Some troubles due to imperfect eyes, such as headaches and nervousness, are not always recognized as associated with those organs. Sometimes a child in school is thought stupid when the trouble is that he cannot see what is written on the blackboard. A wise plan has been adopted in many schools in recent years, under which the eyes of each scholar are tested to determine whether or not he needs glasses. Properly adjusted glasses not only bring relief to strained eyes but so improve general health that everyone ought to welcome an examination of his eyes, and if necessary the adoption of proper glasses.

In ordinary life, through ignorance and carelessness we frequently use our eyes unwisely and in such a way as to invite or increase a tendency to eye trouble. A few general suggestions, therefore, may be profitably remembered by everyone.

**Illumination.**—By changes in the size of the pupil considerable variation in intensity of illumination can be met, since the pupil opens in dim light and closes in bright. Too dim light, as for instance that at twilight, taxes the eyes severely if one tries to use them for exacting work, like reading. On the other hand, very bright light is equally injurious, so that one should not allow sunlight to fall upon a page he is reading.

**Flickering Light.**—A light whose intensity is constantly changing is very tiresome. It is injurious to read by candle-light, not so much because it is dim, as because it is not steady. Reading in the cars is very taxing because the images on the retina are those of an object which is constantly shaken by the motion of the car.

**Resting the Eyes.**—Eyes are made for use and if properly treated will grow stronger, but if overtaxed they will suffer quickly. Reading fine print or looking intently and constantly at small objects is always severe on the eyes. Everyone whose work requires such application should appreciate the need of giving the eyes an occasional rest by looking off at distant objects, or by ceasing to use them at all. If rested in this way they may be used for exacting work for years without injury.

**Injuries.**—The eyes are too delicate to be carelessly treated and injuries to them usually need the attention of a physician. A particle of dust or a cinder in one's eye can usually be removed with ease, however. In most cases tears will quickly wash it over the surface to the tear duct. This process may be assisted by seizing the lids with the fingers and lifting them away from the eyeball, when the tears that accumulate will ordinarily dispose of the dust. The eye should not be rubbed. If the dust particle is under the lower lid, this can easily be lifted and the particles be removed on the corner of a handkerchief; if it is under the upper lid, this can be rolled up gently over a lead pencil. A physician should, however, take care of any serious eye trouble.

## CHAPTER XXII

### THE EAR

Although externally the ear does not appear to be so delicate an organ as the eye, yet as a sense organ it is scarcely less intricate in structure, or necessary in daily life. It has been noted that the eye is quite protected in its rather deep socket; but the ear is yet more secure, being set deeply into and almost surrounded by the temporal bone of the cranium. For convenience in description it is treated as though in three parts, the outer, the middle, and the inner ear.

**The Outer Ear.**—The portion of the ear which protrudes on the side of the head is made up largely of skin, containing several small pieces of cartilage which give it shape. In many animals the outer ear is large and acts as an organ for gathering sound waves and leading them against the ear drum inside; in man, however, this use of the outer ear is practically gone, and it has no special function. Muscles for moving it, which are highly developed in many and especially in four-footed animals, are present in man also, but have degenerated through lack of use. The old-fashioned ear trumpet was merely an auxiliary contrivance for collecting more sound waves and conducting them into the ear.

The canal leading into the head is called the **external auditory meatus**; Fig. 181. This comes to an abrupt ending against a thin membrane, the **ear drum,** or **tympanic membrane.** The canal dips downward a little as it goes inward, and this fact explains how it is that water may get into the ear when one has the head under water when swimming, and why it can only be gotten out by tipping the head to one side

and jarring it. In the skin which lines this canal are numerous glands that secrete a substance which partially evaporates and leaves what is called **ear wax.** This seems to have little function, but it should never be interfered with except by a competent physician.

**The Middle Ear.**—The middle ear is a space just inside the ear drum (Fig. 181) and is scientifically called the **tympanum.** The cavity is not large and is surrounded by bone on all sides save at a few points, which will be especially noticed later. On the lower side of this cavity is an opening leading into the **Eustachian tube,** which passes down to the throat. On the inner side of the tympanum are two small openings, which lead to the inner ear, but which are closed by membranes; the upper one is the **foramen ovale,** the lower, the **foramen rotundum.** At the upper part of the tympanum are some minute pores leading into spaces, called the **mastoid cavities,** in the surrounding bone. Reaching across the tympanic cavity is a chain of three little bones; Fig. 181.

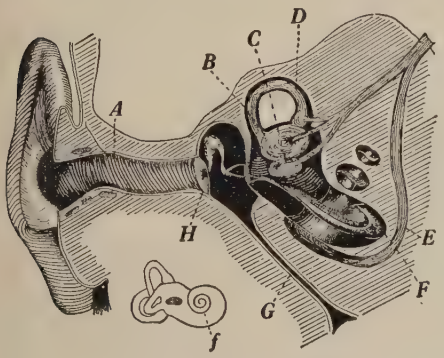



FIG. 181.—DIAGRAM

Showing the structure of the ear. In the lower figure the inner ear is shown natural size. In the upper figure the external ear is shown much too small relatively to the size of the internal structures. The oblique shading represents bone. *A*, external meatus; *B*, utricle; *C*, saccule; *D*, semi-circular canal; *E*, nerve; *F*, cochlea; *G*, Eustachian tube; *H*, tympanic membrane; *f*, cochlea.

**The Eustachian Tube.**—The Eustachian tube serves two very important functions. First, it allows air to go in and out, between the ear and the pharynx. At first thought it seems odd that there should be any connection between the ear and the throat, but such connection is necessary to keep

the air in the middle ear at the same pressure as that outside, so that the ear drum may be kept flat. The Eustachian tube is, therefore, of especial use in enabling one to adapt himself to different altitudes. At the sea-level, atmospheric pressure is much greater than on the tops of mountains; if the Eustachian tube did not thus regulate internal pressure in the ear, the drum would sometimes be pressed inward or again outward, perhaps to the breaking point. The Eustachian tube is also useful as a drainage way for the middle ear; its lining is ciliated, and mucus which is formed in small quantities in the tympanum is thus carried to the pharynx.

The Eustachian tube is not generally open; it is rather in the condition of a thin rubber tube, with its sides collapsed. Its closing prevents the voice, which is produced in the voice box just below the opening of the tube into the pharynx, from passing up the tube and creating a loud disturbance during ordinary conversation. Moreover, if the tube were constantly open, air would be continually passing in and out of the middle ear as one breathes. This would keep the thin membrane of the drum and the partition between the middle and inner ear cavities under constantly changing pressures and irritate the hearing organ seriously.

**Mastoid Cavities.**—Whether or not the mastoid cavities are of any value is not clear; but they are sometimes the cause of serious trouble. When there is inflammation in this region and the cavities become filled with pus, producing a disease called **mastoiditis,** the most skilled physician or surgeon should be given charge of the case. The distance from the mastoid region to the brain is so short that inflammation can easily spread through the thin, bony walls of the brain cavity, and if the brain becomes involved the trouble may be fatal.

**The Ear Bones.**—There are three tiny bones stretching in a zigzag course across the middle ear cavity, from the ear drum to the foramen ovale; Fig. 182. The first is the **malleus** (hammer), and is fastened to the drum at one end. From

there it extends upward, where it is attached to the second bone, the **incus.** This bone has something the shape of a blacksmith's anvil (hence the name incus) and one projection from it extends downward into the cavity again, connecting with the third bone, the **stapes** (stirrup), which ends in a broad, flat area, fitting into the opening mentioned above as the foramen ovale; Fig. 182.

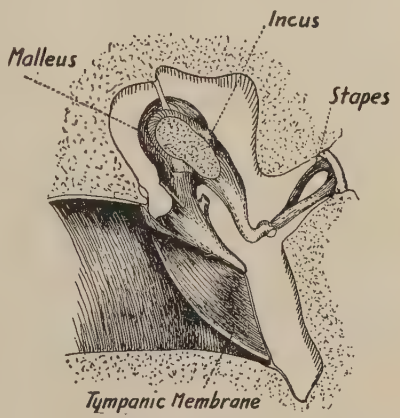



FIG. 182.—THE EAR BONES
Stretching across the middle ear from the tympanic membrane to the foramen orvale. (Hensen)

The three bones are connected by ligaments, and there is practically no hinge action except between the incus and stapes. Two tiny muscles are connected with these bones; one, the **tensor tympani,** leads from the wall of the Eustachian tube to the malleus bone. When it shortens, it pulls on the malleus and thus indirectly tightens the drum. The other muscle, the **stapedius,** runs from the wall of the cavity to the neck of the stapes, and when it contracts pulls the stapes to one side, thus changing the position of the membrane over the foramen ovale. The value of these muscles will be discussed later.

**The Inner Ear.**—The foramen ovale is a short passage in the bone and leads into a series of cavities which constitute the inner ear. As shown in Figure 181, this cavity is complicated and difficult to understand. Altogether it is no larger than the end joint of the little finger, but it is the location of the whole organ of hearing and of balancing. Inside the foramen ovale membrane is a cavity called the **vestibule,** filled with a thin watery fluid, the **perilymph.** The cavity is

not a simple one, but from its main central portion (Fig. 181) three tubes lead out into the surrounding bone in different directions, make half circle turns and come around into the central cavity again. On the posterior side of this cavity a longer canal, twisted into a spiral form, goes out into the bone.

In this curiously shaped cavity and floating in its fluid are two thin-walled sacs; the larger is called the **utricle** and is connected with the smaller, the **saccule,** by a slender canal. From the utricle membranous tubes, called the **semicircular canals,** run through the three half circular canals noted above. Extending from the other sac, i.e. the saccule, and following the course of the spiral tube in the bone, is another membranous canal. This spiral bony canal and its contained membranous canal are together called the **cochlea.** The utricle, the saccule and all the tubes in connection with them are filled with a clear, watery fluid, the **endolymph.**

## FUNCTION OF THE SEMICIRCULAR CANALS

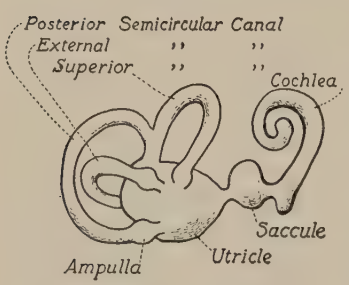



Fig. 182 A. Diagram of ear parts

The ear is usually thought of as an organ of hearing rather than one of balancing, but the semicircular canals are concerned with the latter function.

Figure 182A shows that each canal has a swelling, an ampulla, at one end near where it leaves the utricle. The inner structure of an ampulla is shown in Figure 183.

On one side of the ampulla is a ridge, and on top of the ridge are a number of hair-like projections, among which are lime granules. The direction in which the canals run should also be noted. No two pass around through the bone in the same plane; one lies approximately in a horizontal plane, another in a vertical plane, in a right-to-left direction, and the

third in a vertical plane, in a front-to-back direction. Thus, one of these canals is located in each of the three planes of space, in each of the main directions in which the body can be inclined.

If the location and structure of the canals is clear, their manner of functioning can be readily understood. They are filled with endolymph, and when the head is rotated, this fluid acts as water does in a pail or glass jar when the latter is turned around in the hands. The liquid scarcely moves, but the pail or jar slips around outside the liquid. If there were threads attached to the sides of the pail, these would be bent back and forth by the water slipping over them as the pail was turned first one way and then the other; in like manner, if the head is tipped from side to side, or forward and backward, the endolymph in the canals tends to stay in its original position, while the canals slip around it. This makes the hair-like projections on the crests in the ampullæ bend to and fro, and since nerve fibres end in these ampullæ, this swaying of the threads creates a message which is carried to the brain. In tipping in any direction, the lime granules will settle on different parts of the ampullæ. This will irritate nerves ending in these regions, and the result is that one has a sensation of inclining from side to side, of falling or of rolling over, as the case may be.

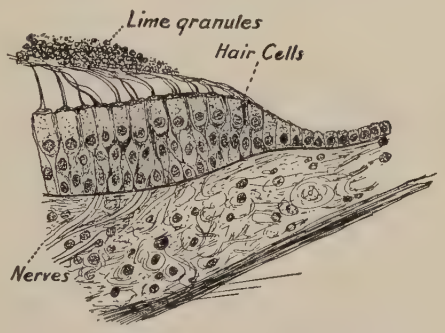



FIG. 183.—A SECTION OF ONE OF THE AMPULLÆ OF THE SEMI-CIRCULAR CANALS (Kolliker)

Of course all the movements one makes are not in the exact planes in which the semicircular canals lie, but they are at

least somewhere between them, in which case the endolymph in two of the canals is moved, and from the resulting sensation one judges the direction of the body motion. These facts, too, explain why children who have been whirling about on their feet in one direction for some time become dizzy. If a pail of water is whirled long enough in one direction the water will finally get to whirling with the pail; and if then the pail is suddenly stopped the water will keep on moving for some time. In the same way, a whirling child sets the endolymph moving in the direction in which the canals go, so that the latter no longer slip around outside the endolymph; when the child stops whirling the endolymph keeps on moving in the canals, and though the body is quite erect, messages continue to go to the brain, and the resulting sensation makes the nerve center feel that some other position of the body must be sought. Messages are consequently sent out to some muscles to relax and to others to contract. As a result the child makes staggering movements, or falls over. Relief can be obtained quickly by whirling in the opposite direction for a moment, thus compelling the endolymph to overcome more friction and sooner become quiet.

### THE STRUCTURE AND FUNCTION OF THE COCHLEA

The shape of the cochlea tube, as it winds into the bone of this region, has already been described as that of a spiral. The diagram in Figure 184, which represents the cochlea as unwound and straightened out, makes this matter of the connection between the cochlea and vestibule clear. The part of the structure which has to do with hearing is the dotted horizontal tube, in the walls of which the auditory nerves end. The cochlea is large where it leaves the vestibule, but grows smaller as it coils. It has often been likened to a snail's shell, and indeed takes its name from that fact.

Extending through the membranous tube (marked cochlea in Figure 184) is a peculiar organ, a sketch of which (highly

magnified) is shown in Figure 185. This is called the **organ of Corti,** and in it are the endings of the auditory nerve fibres. It is the real organ of hearing, just as the retina is the organ of sight. The manner in which it is affected by sound is not fully known, but it is probably something as follows:—

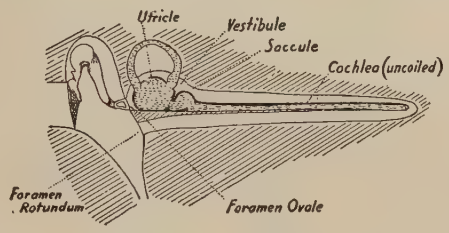



FIG. 184.—DIAGRAM
Showing the relation of the cochlea (uncoiled) to the vestibule and other parts of the ear.

Sound is produced by vibrations or waves of the air. When waves reach the body they pass into the external auditory meatus until they come against the tympanic membrane or drum. As the waves fall upon this they set it to moving at the rate at which they strike it. This movement of the drum will evidently be transmitted to the ear bones attached

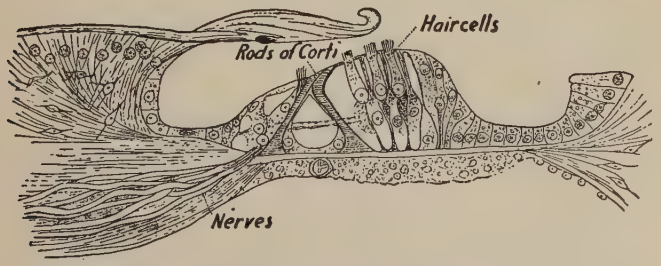



FIG. 185.—SECTION OF THE ORGAN OF CORTI
Highly magnified. Showing the real hearing part of the ear. (Retzius)

to it and by their motion the end of the stapes is pulled back and forth in the foramen ovale. This motion will in turn produce a similar set of little waves in the liquids of the internal ear, with the result that the whole mass of liquid will vibrate just as rapidly as the air outside the head. As a re-

sult, the organ of Corti, which lies quite freely in the liquid, will also be thrown into vibration. In this organ, as we have learned, are the ends of the nerves of hearing, and it is supposed that the slight shaking they thus receive is sufficient to stimulate them so that they transmit impulses to the brain, which are then interpreted as sound.

**Perception of Pitch.**—The method by which the ear recognizes high and low tones is not fully understood, but it appears to be in part based upon a very simple fact. Sound is the result of air waves, and the different pitches are due to waves of different degrees of rapidity. In high sounds the rate is very rapid, in low sounds it is slow; the longest strings of a piano vibrate about thirty-three times per second, the shortest strings about four thousand two hundred times. If one stands close to a piano and plays a loud note upon a flute, for example, and then stops, he will notice that he can hear the same note sounding in the piano for several seconds. The waves of air starting from the flute have passed into the piano and strike upon the various strings. There is one string in the instrument that naturally vibrates just as rapidly as the waves which come from the flute, and these wave motions from the flute set that particular wire into vibration, so that even after the flute is silent, one can hear a faint sound from the piano string. If two notes were played near the piano at the same time, two wires would be set into vibration, etc. This phenomenon takes place according to a principle known as that of **sympathetic vibration.**

By reference to Fig. 185 it is noted that the rods of Corti and the "hair cells" seem to stand on a straight, basal membrane; this is really a shelf-like curtain which is attached to the core of the spiral cochlea along one edge, and to the outer curve of the tube on the other, dividing it into two spaces lengthwise. This **basilar membrane** is made up of about 24,000 threads (Retzius) of practically as many lengths. These basilar membrane threads, it is thought, vibrate at different rates,

much as do the various wires of a piano. When, therefore, the liquids in the inner ear are thrown into vibration, it is evident that some part of the organ of Corti will naturally vibrate with exactly the same rapidity as the movements of the liquid, according to the laws of sympathetic vibration. Thus for every different sound a nerve fibre will be stimulated, and the brain recognizes the different pitches. While this general theory of tone perception seems to be reasonable and correct, we must admit that as yet no one knows precisely what part the organ of Corti plays in the appreciation of sounds.

**Loudness of Sound.**—Loudness of sound depends, not on the rate at which air is moving in waves, but on the size of the waves; not on the rapidity of vibrations, but on their amount. This we know from the simple fact that a piano string struck heavily will give out a loud sound; if struck gently, a low sound, though of the same pitch as when struck heavily. Violent movements in the air are set up when the string is vibrating back and forth through considerable distance after being struck hard, and these start large waves in the surrounding air, which however vibrate at the same rate as if the wire had been struck gently. These violent movements are finally transferred to the inner ear over paths we have already discussed, and thus the nerve endings in the organ of Corti are greatly irritated. One interprets this strong stimulation as loudness of sound; faint sounds are conversely due to very slight air waves and slight nerve stimulation.

When listening intently to catch some faint sound, almost everyone strikes the same instinctive attitude. The body is held very quietly, the ear turned in the direction from which the sound is expected, and the whole attention is focused on the ear. In the perception of faint sounds, slight changes occur in the middle ear, and the purpose of these changes may be understood from the analogous action of a drumhead.

When a drum head is loosely drawn, the drum will sound very well if struck hard enough with the sticks, but if the drummer merely touches the head or hits it very gently, no sound of consequence comes from it. If, on the other hand, the drum head is drawn tight by shoving down the straps on the cords at the sides of the drum, the merest movement of the sticks on the head produces a very distinct noise.

In the middle ear the two tiny muscles, mentioned on page 365, are so placed that they can tighten the membranes bordering on the middle ear, so that the least movement of sound waves in the air can be detected. The **tensor tympani** draws the ear drum tight, and the **stapedius** pulls on the stapes and adjusts the membrane over the foramen ovale; the ear is thus put into condition for perceiving very faint sounds.

**Quality of Sound.**—As has already been pointed out, the quality of one's voice is determined not entirely by the nature of the vocal cords, but by the size and shape of the cavities of the trachea, the pharynx, the nose and some smaller cavities in the bones of the upper part of the nose. The air in these cavities is set in vibration by sound waves, and the people who are listening to one's voice get the effect of all the incidental influences of the cavities upon the sound. How marked the influence of these centers is may be proved by merely closing the nasal passages—grasping the nose between the fingers while talking.

## DEAFNESS

Defective hearing is due to a variety of circumstances. In elderly people it is generally caused by the stiffening of the ear drum or other delicate membranes so that they are not so sensitive to slight sound waves as formerly, or it may be due to the fact that the bones of the middle ear have become more or less rigid and do not move readily.

In younger people, and in those who become temporarily deaf, the trouble usually is that the Eustachian tubes have

become closed by some inflammation of the tissues about them. This often happens to a person who has catarrhal troubles. A bad "sore throat" may produce deafness or "ringing sounds" in the head for this simple reason. The result of the closure of the Eustachian tubes is that the pressure of air in the tympanic cavity, or middle ear, becomes different from that outside (whether greater or less, the result is the same) and the membranes involved will not act well under these strained conditions. Such circumstances impose a kind of stress on the fluids of the inner ear, so that they can move very little, if at all. "Ringing noises" may be due to the fact that the fluids cannot move in the normal way, and these being under extra stress, a large proportion of the nerve endings in the ear feel the strain, and innumerable mild messages go to the hearing center in the brain. These may be so continuous and disturbing as to induce headaches and generally disagreeable results. One should not allow the trouble to continue long without submitting it to skilled treatment. If a "buzzing in the ears" or temporary deafness occurs as the result of a cold, a physician should be consulted, since such troubles, left unattended, may result in permanent deafness.

The other so-called special senses are taste, smell and the sense of feeling, including touch, heat and cold. Each of these has been considered in previous chapters and need not be discussed here.

## CHAPTER XXIII

## THE CONTROL OF HEALTH

**Personal Hygiene.**—As one's usefulness in the world depends directly on the quantity and quality of mental and physical energy he has to spend, it is necessary to know the important factors which contribute to personal health and efficiency such as in food, exercise, sleep, etc. We cannot exercise too great care in the selection, preparation and eating of our food, or we shall yet condemn ourselves to ill-health by our unwisdom.

**Foods.**—Our food should be selected with reference to a proper balance of elements as outlined in Chapter III. Proteids, carbohydrates, and fats are all vitally necessary, as well as certain constituents (vitamines) found in vegetables and milk. The action of vitamines is not yet thoroughly understood, but it is known they play a very important role.

**Excess of any food qualities to the exclusion of others will finally, though not immediately, reduce the body to weakness; this must never be forgotten.**

Constipation, or the failure of food materials to be steadily carried through the digestive tube, results in abnormal decomposition and the formation of poisons which, absorbed, circulate through and injure the whole body. This condition can be avoided in most cases (*a*) by the use of coarse breads, bran, graham, and the like; (*b*) by the use of leafy vegetables, the larger part of which are never absorbed but become a "roughage" which, in contact with the intestinal wall, provokes peristalsis; (*c*) by the right use of fats and oils; (*d*) by the use of fruits. The old saying, "An apple a day keeps the

doctor away", may be taken seriously. (*e*) Temporary laxatives, such as drugs, must not be employed frequently, or the system will come to depend upon them. Paraffin oil (American oil) is one of the safest and best laxatives and is not unpleasant to the taste. (*f*) By the use of plenty of water. Two quarts per day is not too much for a person weighing 150 pounds. Water taken in liquid foods is needed in addition to this amount. (*g*) Exercise, by which the body is repeatedly bent into various positions, subjects the abdominal organs to various pressures, the nerves are awakened, and the blood flow quickened.

*Salt and condiments*: The fact that salt ($N_aC$) leaves the body in the same form as it enters makes it no less a necessity. In 1000 parts of blood there are 5.5 parts of salt. Its intimate role in the body is not entirely understood. Spices have no food value, and should as a rule be eaten sparingly. Flavors make foods more palatable, and in themselves are generally harmless.

*Beverages:* Coffee and tea are the commonest table beverages exclusive of water. In using them one must remember that their food value is nil, save for the cream and sugar usually taken with them. Caffein, in coffee, excites certain nerve centres, and hastens kidney excretion, necessitating abnormal demands on the organs involved. Thein, an ingredient in tea, seems to prevent free digestive action of saliva on starch. The use of either tea or coffee cannot be commended, and must be strictly limited. Cocoa and chocolate have decided food value, but contain also theo-bromine which has the same properties in general as caffein.

The so-called "soft drinks," soda waters, etc., may have small sugar value, but as generally taken, interfere with the appetite for wholesome food, and besides the purchase of them is a waste of money.

**Irregular Eating.**—The habit of eating between meals is a specially vicious one if the regular meals are the proper time

apart, and are adequate for the kind of work being done. If one feels faint or nauseated before a meal, the probability is that his last meal was deficient and a lunch would have been very wisely taken. The stomach, digestive organs and glands must be given rest, just as we know muscles and nerves demand it. The appetite may suggest irregular and frequent eating, but its suggestions may not always be followed. See page 51.

**Alcoholic Beverages.**—The effect of alcoholic beverages upon the nervous system has already been discussed.

**Exercise.**—Muscles comprise fully 40 % of the body weight, and their condition, healthful or otherwise, affects the body as a whole. The blood, going to and from every tissue, carries away materials from muscle of a nature unlike that taken from any other part of the body. As the blood stream hurries on, every other tissue, e. g. nerves, glands, etc., is influenced by what has gone into the blood stream from muscles.

These changes which take place when a resting muscle begins to act are as follows: (*a*) Sarco-lactic acid is produced and replaces the alkaline character of resting muscle. (*b*) Loosely combined oxygen is speedily associated with carbon forming $CO_2$. (*c*) Glycogen already stored in the muscle is transformed and poured into the blood as dextrose. (*d*) The temperature of the muscle is raised.

These changes, happening in the muscle itself, are, through the blood stream, felt throughout the body, with many accompanying results, some of which are: (*a*) The respiration is quickened and as a result the air is rapidly changed in the lung recesses and the respiratory muscles are exercised and given new "tone." (*b*) The heart beats faster, all blood tubes are thus flushed and their own muscular walls called into action. (*c*) The mechanism which regulates the temperature of the whole body is roused and put to work. (*d*) Blood and lymph are forced away from points where they may have

become sluggish in their flow. (*e*) The digestive system receives a reflex stimulus and is much benefited.

Exercise which comes through physical work directed to some useful, productive end, brings its most genuine and cheerful satisfaction. Play differs from most work in its excess of mental exhilaration, its spirit of winning, its call for particular skill, its social companionship. Exercise, to be of value, should be vigorous, though not to the point of strain; it should call for repeated moderate action of the same set of muscles rather than a few severe or sustained contractions. Gymnasia offer opportunities for varied exercises which have been selected with the advice of trained directors to meet the individual need for the correction of faulty physique.

**Sleep.**—Sleep is the great restorer of the nervous system. One should sleep with wide-open windows or in sleeping porches. The hygienic reasons for sleep are these: (*a*) Every other system of organs except the nervous system can secure rebuilding during waking hours, if it is deliberately excused from action; but unconsciousness is the only condition which permits nerves to "let go." (*b*) Sleep gives the time necessary for the more complete elimination of wastes. A thorough freeing from katabolic products cannot occur while new ones are constantly added to those in the blood and lymph. This purification can, however, be largely accomplished in eight consecutive hours of total inactivity in sleep. (*c*) Sleep permits that relaxation which cannot occur when one is active mentally. A kind of tone or tension pervades the entire system normally when awake and this needs to be excluded regularly.

**Hygiene of Particular Organs: Eyes.**—No organ of the entire body is more intricate than the eye. Its defects, if any, have a far reaching influence on other organs, e. g., serious digestive irregularities, headache and nervousness often result from eye-strain. If these symptoms are present, or if it is difficult to see objects clearly unless held very near

(6 or 8 inches) or very far away, or if the image of the object is blurred in any way whatever, a skilled oculist should be consulted to remedy the defect. When reading book or paper of average sized type, it should not be held nearer the eye than sixteen inches; nor should the focussing muscles be obliged to act for that distance for long periods without rest. To obtain a change in the focussing requirement when reading, look about the room or out of the window occasionally.

Too intense light is apt to be used. It is only by actual strain that the eye can function in our customary brilliant illumination and if a glistening paper or picture is being examined the result is all the worse.

**Ears.**—To preserve good hearing, nothing must interfere with any portion of the hearing apparatus. No small object should be allowed to touch the ear-drum, much less puncture it. Ear "wax" should be removed with much care, and not permitted to collect.

The greatest danger to the ear lies in its relation, via the Eustachian tube, to the throat. Inflammation of the pharynx can thus spread to the middle ear, and cause pus formation either there or in the nearby mastoid cells (page 364). It is difficult to cure such a condition without endangering the hearing function.

**Social Hygiene.**—By this term is meant the relation which the mingling of people in numbers has upon the health of each one, and of all collectively. In a general way, the health of a community is the sum total of the health of its individuals.

Ever since the germ theory of disease was established by Pasteur, it has been well known that the health of a home or the health of a whole community may be determined by the health or the sickness of a single individual. The process of the transfer of a disease from one person to another is termed a process of **infection.**

**Infection.** — Quite a contrast with the days of long ago,

we now know that many diseases are definitely passed from one person to another either (1) by contact, or (2) by taking into the body "particles" given off from the body of the sick individual. Other diseases are caused by the body being invaded by certain of the lower animals (e. g. malarial organism, trichina), or by bacteria.

"Contagious" and "infectious" diseases are now considered essentially identical, being **communicable.** Among these are typhoid fever, cholera, measles, mumps, whooping cough, smallpox, — communicable from man to man. From the lower animals man "catches" tuberculosis, anthrax (splenic fever) from cattle, malta fever from goats, malaria from mosquitoes, plague from rats, and tapeworms from various meats.

The main problem in avoidance of disease concerns those which, in bacterial form, are passed from man to man. These organisms secure an entrance generally in one of three ways: (1) in the food we eat; (2) in the air we breathe; (3) by way of the skin, through natural pores or through injured surfaces.

Two fundamental facts of bacteriology must be kept in mind; bacteria thrive either when in moist substances or when dry or semi-dry so that they may float in the air, either free, or attached to dust. Dust blows about and settles everywhere, e. g. on clothing, hands and face, on solid and liquid foods if exposed, eating and cooking utensils, furniture of all sorts, curtains and floor coverings. **These are mentioned that we may not forget what may be sources of bacterial infection,** and how thoroughly all the articles in a room with a sick person may be the lodging places of disease bacteria. Such articles as are nearest him are most liable to carry them, e. g. personal clothing, bedding, handkerchiefs, knives, forks, spoons, dishes, and all containers of waste material.

After handling such articles as these just mentioned, if one is to safely guard against infection, the hands should be thoroughly **disinfected** by using germ-killing washes, such

as 2% carbolic acid solution, or a very weak (0.1%) solution of corrosive sublimate. Some of the germ-laden dust from clothing or bedding may have been breathed in, and an antiseptic solution should be used as a mouth wash and gargle, as well as nasal spray.

**As a rule, washes for the skin should never be used for mouth or nasal disinfection.**

Recently opinion has inclined to the belief that many diseases are spread by the **droplet method;** e.g. when the patient, or carrier of the disease germs, coughs, sneezes, or even talks, he expels into the air minute droplets of the mucuous fluids of the mouth or near-by breathing passages. These droplets float about in the air and may be breathed in, or fall on utensils or foods which may later be put into the mouth, and thus the well person be infected by the bacteria which are in these droplets.

**Any person who is ill, even with a cold, should never fail to use a handkerchief over the nose and mouth when coughing or sneezing and should never face toward a nearby person when talking, laughing,singing, or the like.**

The period of time which usually elapses between infection and the actual on-coming of the disease (called the incubation period) varies much even with exposures to the same disease. This is because the body is in better physiological condition at one time than another, or, in other words, possesses more **resistance.** Persons differ greatly in their susceptibility to disease and some may even be immune while others are very liable to a given disease. The following table is given to indicate the time during which a person, knowing of his exposure to some disease, should avoid close association with others:

| | |
|---|---|
| Small-pox. . . . . | 14 days |
| Measles . . . . . | 10 " |
| Scarlet fever. . . . . | 3 " |
| Diphtheria . . . . . | 3 " |

| | |
|---|---|
| Chicken-pox | 20 days |
| Whooping cough | 21 " |
| Cholera | 10 " |
| Typhoid fever | 14 " |
| Mumps | 24 " |
| Infantile Paralysis | 28 " |

**Immunity.**—In a previous chapter (page 72) we have defined immunity as a condition of the body such that it is not susceptible to a communicable disease even when intimately exposed to it. For example, the same mosquito (genus Anopheles, and carrying malarial germs) biting a man and a bird, conveys malarial fever to the man but not to the bird. Another genus of mosquito (Culex) biting both, causes malaria in the bird but not in man. Each organism is naturally **immune** to the bacteria which cause a disease in the other.

Immunity cannot in any way be secured against some maladies, e. g. tuberculosis. Immunity is being secured against an increasing number of diseases by artificial and harmless means. The discoveries made by Louis Pasteur marked what may justly be considered the most important epoch in the history of medicine, and what may almost be called the physical salvation of mankind.

To understand how immunity may be brought about requires attention to the relation which exists between the invading bacteria and the person invaded.

When disease bacteria from any source obtain entrance to the human body, they soon become vigorous and multiply very rapidly because of the warm temperature and of the nutrition they so easily absorb from the body fluids. Under favorable circumstances a single bacterium of certain kinds may give rise to as many as 17,000,000 descendants in twenty-four hours. Passing from the respiratory or digestive organs into the blood or lymph, they give from their bodies substances called **toxins,** which are often very poisonous, and cause the discomfort and symptoms of the disease. The cells of the

body (probably those of the blood vessels in particular) being irritated by these toxins, endeavor to defend themselves by giving off materials which nullify the poisons. These substances are called **antitoxins.** If the body cells can create sufficient antitoxin rapidly enough, the bacteria as well as their products are overcome, and the person will soon be well again. It is quite obvious that the blood of a person so recovering contains antitoxin substances which will make him safe from similar attack so long as they last. He is then said to be **actively immune** to that special disease.

One may secure immunity against some diseases by means other than first going through a period of sickness with it. The commoner means are by vaccination and by serum inoculations or injections. The principle on which both these procedures work is this: if, instead of virile disease bacteria, very weak (attenuated) germs, or the toxin secreted by them, are introduced into the human body through a shallow abrasure or cut in the skin (vaccination) or by hypodermic injection (injection or innoculation), enough antitoxin is immediately produced by the body so that the weak germs are killed off and the toxin made of no effect. With antitoxin thus on hand, the body has a "running start" and can successfully compete against the invasions of strong, vicious bacteria of the same sort. This is the manner of procedure against typhoid and small-pox. The wide use of vaccination for small-pox and innoculation for typhoid fever has thoroughly established their reliability and safety. Persons so rendered safe from a certain disease are said to be **artificially immune.**

Instead of injecting weak and dying bacteria or the toxin characteristic of them, the body can be fortified against some diseases by injecting antitoxin taken from some animal which has had the disease and recovered from it; this is the case when serums are injected to ward off diphtheria. Curiously enough, the body cells can be deceived in this way, and on becoming "conscious" of the presence of some antitoxin will

busily begin to make more like it. A quantity is thus soon on hand sufficient to combat successfully the heaviest infections.

**Home and School Hygiene.** — Since at least one half the life of each person is spent indoors, it is very essential that homes, school buildings, etc., should be as conducive as possible to the health and general welfare of mind and body. Many matters of building hygiene apply equally to dwellings and school-houses, so, unless specially designated, the following considerations pertain to both.

Primarily a home should be located with reference to its water supply, drainage, air supply, and light. Beauty of surroundings, freedom from noise, relation to markets and transportation conveniences, and congeniality of neighbors are likewise considerations of real importance.

**Location and Water Supply.** — Wherever one is, he cannot live unless provided with pure water in unfailing quantity. If wells are the only source of water, they must be carefully isolated from contamination by house or barn drainage. A knowledge of "the lay of the land" where the well is dug should be obtained so that underlying layers of rock or impervious earth (clay) may not lead impure water into the well from a distance. The area immediately about such a well should be raised decidedly above the general level, and cemented over for a distance of at least six feet on all sides of the opening, to prevent rains from washing surface debris either directly or indirectly into the well. It should be covered tightly to prevent leaves, dust, foreign matter, or small animals from getting into the water.

If one is contemplating living in any given city or village, the source of its water supply, its treatment, the manner of its storage and method of delivery should be investigated. No portion of a water-shed affecting a supply should be a place of human habitation unless all the circumstances of such a house are known, and its drainage prohibited from entering the waters destined for household use.

In case a town supply must be taken from a river, pond, or lake, the science of sterilizing, softening and clearing water is so highly developed there is no reason why wholesome waters should not be secured. Clearness, "softness," and lack of odor do not insure *pure* water. Its bacterial content is of more significance than any other single factor; and the number of bacteria is of little consequence as compared with their kind. Bacteria which thrive in decomposing organic material should not be present, particularly such as are found in the human digestive canal. If such are found, it is obvious that insanitary drainage from human dwellings is somehow entering the supply, and the health of every person using this water is in imminent danger.

The temperature, except for affecting its palatableness, has nothing to do with its desirableness. If ice is used in water, one should be certain that it, in turn, is made from pure water, and in its use one should remember the physiological fact that cold temporarily slows or even stops the action of life processes.

**Location and Drainage.**—Formerly, if the basement of a house kept dry, little was thought of other drainage. The water wastes were thrown on the near-by ground, and either allowed to sink in, or to run into an open ditch. Solid matters were allowed to collect wherever they might.

In modern times, large amounts of water are used in washing, rinsing, house-cleaning, and the like. Lavatories, bathtubs, and the sanitary water-flushed toilet have become necessities of civilization. Rainwater should be conducted away and not be allowed to fall from the eaves, as this undermines the foundations and creates a damp, unwholesome basement.

Houses should be so located that all waste water can be conducted away to a safe distance; in order to do this the house should stand above the general level so this drainage may be easily and surely secured.

**House Construction.**—A dry basement is very essential.

It is secured by keeping surface water away from foundation walls by tight bottom construction, and by a drainage exit for any water which may enter in unanticipated ways.

The side walls of a building are much warmer if made in at least two thicknesses (preferably three) with an air space between. This same method of insulation against a temperature change is used in the construction of refrigerators and incubators, where maximum uniformity in temperature is wanted. Windows should be numerous, both for purposes of light entrance and for ventilation. The doors as well as the windows should be fitted with screens so that insects may be kept out, as some of these are now well known carriers of numerous kinds of disease "germs" (bacteria).

Walls and floors of rooms should be so finished as to be easily kept free from dirt and dust. Fancy wood-work in which dust collects and which is cleaned with difficulty, is unhygienic.

**Location with Reference to Light and Air.** — Whether in city or country, one should keep in mind the need of adequate light and the vital necessity of plenty of pure air when deciding on a place of residence. Dense shade from trees or an environment of high buildings makes the eyes work under difficulties, necessitates the expense of artificial light, and constitutes a condition of general unwholesomeness. This is because sunlight is one of the most effective agents in the destruction of bacteria. Sunny rooms are not merely well lighted, but are healthful. This germicidal action of light should be utilized by putting clothing, rugs, and house-furnishings in the open air on sunny days.

**Artificial Light.**—Of the modern methods of artificial lighting, electricity is by far the most convenient and hygienic. Its convenience is obvious, and its use is hygienic because there is no leakage or odor as with gas or oil lighting. Electric lighting systems have now been developed so that a home in the country may be lighted by electricity.

In the use of gas, care should be taken to prevent any leakage, to adjust the mixture of gas and air at each burner, so as to obtain the most light, and to obviate vitiating the air with unoxidized gas.

Acetylene gas plants are often placed in private houses, especially in the country; here again leakage should be particularly guarded against, and users should clearly understand its explosive qualities. Kerosene oil may be burned where other artificial illumination is not available, but extreme cleanliness is necessary to prevent bad odors and to secure maximum light.

In all kinds of illumination, our tendency is to employ too brilliant light and to use too little care in preventing light from shining or being reflected directly into the eyes. From whatever source, light should come from over the shoulder, not from the front or side.

**Artificial Heat.**—Stoves are still used for heating houses, even though they are somewhat unsatisfactory for this purpose. They are unsatisfactory for several reasons: Dust and dirt accumulate about them; the distribution of the heat in the room is uneven; the floors remain cold above the basement; poisonous gases may escape (from coal stoves); and the danger of fires from a number of stoves in one house is increased. Central heating from a furnace obviates all these objections. Each of the different sorts of central heating systems, hot air, steam and hot water, has points in its favor as well as against it.

*Hot Air Furnace:* The hot air system brings fresh air into the house, at such temperatures as to obviate cold drafts, and in this respect is a most desirable method of heating; but dust is almost certain to collect in the furnace and delivery pipes, and be brought up in the air current. As winds greatly modify the delivery of hot air to different rooms in the house, the equable distribution of the hot air on cold, windy days is not always possible.

*Steam System:* In this system, the steam pressure can be

raised to such a degree that the radiators can be made very hot in severe weather and every room thoroughly warmed. The objections to steam heat are: The air of a room is heated over and over with no ventilation unless such is specially provided; the radiators may become over-hot and "burn up" the air; and no heat is obtained from the fire till the water is near the boiling point.

*Hot Water System:* This has the advantage of delivering some heat to the radiators as soon as the water is slightly warm. The heat is steady, and the radiators remain warm a long time after the fire is low. The disadvantages of this heating plan are that the radiators never get so warm as with steam, and must therefore be much larger for the same service; furthermore, ventilation must be secured in ways not related to the heating system.

**Ventilation.** — Ventilation is necessary for several reasons: breathed air contains too little oxygen, too much $CO_2$, too much moisture and too many organic compounds in small amounts. Each person vitiates about 1,800 cubic feet of air per hour, and provision must be made for its renewal or the individual becomes inefficient in working power and in resistance to disease, and is reduced to poor health generally.

Of all the many ways of letting fresh air into rooms, the old-time method by way of windows and doors is one of the best; forced ventilation with flues and fans is seldom entirely satisfactory and is very expensive. A good way to ventilate a room is to let fresh air enter near the top of the room, and to let the stale air escape at the bottom as through a fireplace or some similar exit. Fresh air is bound to enter around loose windows and doors.

Especial provision must be made for all buildings where many people congregate as in schools, churches, and theatres. Sufficient air space cannot be secured for such rooms unless they are made very large, or with high ceilings. No drafts, either warm or cold, should be allowed during cold weather;

temperature should not vary more than 2° from 68° F., and the air should be neither too dry nor too moist. In buildings heated with steam or hot water, special consideration should be given the matter of humidity, as very dry air is irritating to the lung membranes and is thus a menace to health. Moisture should be provided in the form of steam, and the supply regulated by an automatic humidometer.

**Furnishings.** — Whatever the use of the building, its furnishings must be such as may easily be kept clean. Fancy wood furniture or iron desks are kept free from dust with great difficulty. Carpets fastened down so that dirt cannot be removed from under them are now little used; only such rugs as can be easily and thoroughly cleaned should be considered practical or desirable. Window hangings and upholstery should also be selected primarily with reference to healthfulness.

**Cleaning of Buildings.** — In performing any cleaning the one prime rule to insist upon is NO DUST, whatever the method used. If the dust is removed and not scattered in the process, the method is excellent. Cloths used in dusting should be oiled to entangle and remove dust, not scatter it as was the case with the old-fashioned feather duster. Preparations for entangling the dust and dirt should be scattered on floors before sweeping them, and unless a vacuum cleaner is used, rugs should be taken out of doors to be cleaned.

In school-houses chalk dust should be wiped from blackboards with a damp cloth or some other dust absorber. The chalk trough below the board should be covered with wire screening to keep hands and erasers from the dust. Slate boards are cleaner than wooden ones, besides largely doing away with the glare from reflected light.

**Disinfection of Rooms and their Contents.** — This procedure as a preventive against the spread of disease is of very much less value than was once supposed. For instance, there seems very little virtue in disinfection after cases of measles,

whooping cough, influenza, pneumonia, diphtheria, or meningitis.

Clothing and bedding which may have been stained by fluids from the body of a sick person should be thoroughly boiled and other articles from the sick room hung in the air and sunshine for several hours to free them from bacteria. Thin clothing hanging in a closet can be disinfected by placing a small sheet, sprayed with strong formalin, in the closet and closing the door tightly for some hours.

If a room is to be disinfected, the permanganate-formalin method is considered the best. The method of procedure is as follows: After sealing the room air-tight (strips of paper can be pasted over cracks), place potassium permanganate (250 grams—9 ounces for each 100 cubic feet of space) in a very deep pail near the middle of the room; the pail should stand on a couple of bricks or similar support as the bottom will become hot. When all is ready, pour onto the permanganate 500 cc. (about 1 pint) of formalin, full strength. The gas from this has poor penetrating power, so that thick clothing, bedding, etc., should be given special treatment, i. e. steamed, boiled or soaked in 5% solution of formalin.

**Special Home Problems: Sewage Disposal.** — In most municipalities refuse from kitchen sinks, lavatories, and toilets is carried away by the sewage system. In smaller villages and country places, private cess-pools, with uncemented walls will, with little attention, take care of the needs of an ordinary house for some years. Such a cess-pool must never be located so that seepage from it will enter any supply of water.

In the country, if privy vaults are necessary, they should be perfectly isolated from flies or vermin and be so closed and treated as to be free from odor. The container should be a removable, water-tight can, the contents of which should be frequently buried, never thrown on top of the ground.

**Special School Problems:** (*a*) **Sanitation of Public**

**Buildings.**—Schools, theatres, and churches are the commonest meeting places of the people of a neighborhood. These meetings afford an ideal opportunity for the spread of disease. Close personal contact is almost inevitable, rebreathing of air is certain, common water faucets and toilets are the rule.

The proper management of a schoolhouse or any other public building is one of its greatest educational influences, as its sanitary arrangements and general cleanliness will no doubt affect those benefited by them.

Too great emphasis cannot be laid on the importance of extreme sanitation in school lavatories and toilets. Any part of the equipment of these rooms which has been touched by the diseased surface of a person suffering from a communicable disease is very liable to be a source from which the disease may be transferred to others.

Drinking fountains, paper towels, and laws compelling the use of only new books are among the most recent developments of sanitary science.

(*b*) **School Nurses and Physical Examinations.** — As children are compelled by law to attend school, it is the duty of the school officials to see that their health is safeguarded in every way. For this purpose school doctors and nurses are employed who inspect the children's health. Their throats, teeth, eyes and ears are examined by experts who either give or suggest skilled treatment for physical defects, thereby removing conditions which might later on seriously interfere with health and usefulness.

Specific results of tonsil and adenoid infections, decayed teeth, eye strain, and ear diseases have already been pointed out in the sections dealing with the physiology of the throat, mouth, and special senses.

**Quarantine Laws.** — By the term quarantine is meant the isolation of a person or persons having, or suspected of having, a communicable disease. This procedure prevents the spread

of communicable diseases. The quarantine period may involve:

1. The time elapsing between exposure and onset of disease.
2. Time of actual sickness with the disease.
3. A detention period after active sickness is past but during which the person may be a "carrier," i. e., be a source of infection to others.

We have already called attention to the "incubation" period of several common diseases in Chapter XXIII. The second period mentioned will differ much with the physiological condition and care given the patient, so that little may be said about it in advance. The period of detention also varies but in no case should a person recovering from a communicable disease be allowed to return to the company of others without permission from a physician. The quarantine law for some minor maladies often reads thus: "Persons suffering from measles, whooping-cough, mumps, German measles, and chicken-pox shall be barred from school for twenty-one days from the onset of the disease." Lessening or lengthening of this period is left to the physician or health officer having jurisdiction.

Houses in which there are communicable diseases should bear a placard so stating; and the Board of Health should furnish a list of communicable diseases, with the quarantine rules applying to them, to all parents who have children in school.

**Municipal Health and Hygiene.** — From the standpoint of health, the city has many of the characteristics of the single home. As the ill health of one or two members of a family may endanger the health of the rest, in precisely similar fashion unhealthful conditions in any section of a city are a menace to the whole city. Therefore authority must be given special groups of men who shall act toward affairs of a city as parents do in the affairs of families.

**Public Commissions and Boards for Safeguarding Public Health.**— The Board of Health, with the co-operation of other Commissioners and Committees, keeps vigil over the health of the entire city. Other bodies which act with them or under their direction are the Water Commissioners, Street Commissioners, Milk and Food Inspectors, and School Nurses. Among the larger responsibilities of such public officials are the prevention of carelessness as to food and water supplies, condition of streets, garbage disposal, the prevalence of noise and smoke, the ventilation of stores, factories, and public buildings, the quarantine of infectious diseases, and provision of opportunities for securing recreation and fresh air for all classes. Their work is said to be that of securing **public hygiene** in contrast to that science and observance which makes for the health of the individual and is called **personal hygiene.**

It is very apparent that only scientifically trained men should be chosen members of Boards of Health, for the lives of hundreds, or hundreds of thousands, are in their hands.

**Public Water Supplies.** — The greatest care should be exercised to secure pure water for towns and cities. Public reservoirs must be filled from sources entirely uncontaminated by refuse from human habitations and must be kept pure. Leaves and dying plants should not be allowed to collect in them, as they become breeding places for bacteria and other unicellular organisms injurious to health.

Conduit pipes and faucets must be of materials which will not vitiate the water. If a water supply is taken from lakes or rivers which are unavoidably contaminated, it should be sterilized chemically or otherwise, and thoroughly filtered. No dependence should be placed on the ordinary small faucet "filters" sold for private use.

**Public Food Supplies: Markets.** — The fitness of foods cannot be determined unless they are traced to their sources, and the method of gathering, packing, shipping, selling, and

delivering is known. Uncleanness at any point in this process unfits the article for use. Contact with human hands always brings in a source of danger; exposure in stores or on sidewalks gives opportunity for infection from many sources. Many foods deteriorate if left at temperatures which permit bacteria to increase rapidly; some containers have surfaces which, under action of the air and acids, will poison the contents. All fruits and vegetables which are not cooked before eating should be thoroughly washed.

The United States Government and the various State Governments, as well as municipalities, have passed laws and regulations governing the production and sale of food stuffs, such as the seeding of raisins, the packing of figs and meat, the wrapping of bread, the canning of vegetables and fruits, and the milling of flour. Inspectors are appointed to see that foods offered for sale comply with these regulations.

Highly nutritious foods like milk are especial breeding places for bacteria and must be handled with extreme cleanliness from source to consumer. Cows must be healthy (no tuberculous condition), stables sanitary, milking men and machines clean (and men healthy), cans and bottles sterile. With the best of care milk receives bacteria from the air; but Grade A milk (for infants) should not contain over 60,000 bacteria per cc. (if Pasteurized, not over 30,000 per cc.), Grade B not over 100,000 per cc., and Grade C (used only for cooking) not over 300,000 per cc.

To be on the safe side, one should always remember that thorough cooking (boiling temperatures or higher) destroys all living matter. Thus, danger from infected food may be avoided; but food free from infection is safer and better yet.

Purity also implies freedom from adulterants; coffee, tea, spices, syrups, milk, powdered and dry "foods "are not infrequently increased in bulk and weight with cheap substitute articles.

Pork should be free from trichina worms, oysters from

typhoid bacteria, cereals and meals from insect eggs and the maggots which hatch from them, vinegar from "vinegar eels."

**Public Disposal of Garbage.** — At each of the many homes in a city there accumulates daily an unavoidable quantity of debris; garbage from the kitchen, waste paper, empty food containers, ashes, etc. Such material cannot be disposed of on the premises, save by use of costly incinerators or by burial. A system of collection at public expense is the only safe and sure way of securing sanitary disposal of such material. "Filth breeds disease" as one often reads, and one protects not only himself but all about him when he insists on sanitation in the matter just mentioned. Garbage, if not burned immediately, must always be kept, until collected, in covered containers which will keep out insects and vermin.

**Street Cleaning.** — The sources of dirt and filth in a city are innumerable. To some extent this dirt adheres to every one. Air currents stir it up and carry it everywhere. The accumulation of dirt and filth in a city should either be washed away, or carried to stations especially fitted for burning it or to places where it may be buried. The city's example of cleanliness or lack of it is one which influences the practices of all the inhabitants. To compel this public cleanliness by law should be the willing procedure of the people. Disraeli, the famous Englishman, once said: "Public health is the foundation on which reposes the happiness of the people and the power of the country. The care of the public health is the first duty of a statesman."

**Public Playgrounds and Parks.** — The providing of playgrounds and parks is necessary, as we now appreciate the vital relation between recreation, fresh air, and rest on the one hand, and effectiveness, health, and readiness for action on the other. These public playgrounds and parks, with the opportunities they afford to leave the crowded sections of the city with their barren walls, their din, smoke, fatigue, and monotony, are the oases in the city desert. Parks are unnec-

essary for those who can afford their own ample yards, or can quickly reach the country in automobiles; but for the vast majority who have no other source of out-door relief, they are indispensable. For many children they undoubtedly mean the difference between living and not living.

**Medical Inspectors and the Control of Epidemics.** — The real nature of communicable diseases, their symptoms, the sources of infection, the method of treatment, the liability and manner of spreading, and the seriousness of the disease to the patient is known only by those well trained in the science of medicine. Medical inspectors are given legal permission and the assigned duty of keeping track of the public health. They give the sick prompt attention and protect others from infection. Without them communicable diseases would be uncontrolled and without proper attention one case might easily spread to thousands. It is the duty of every physician to report cases of communicable disease to the public health officers and to co-operate with them in every possible manner. The people, in turn, should give their willing support to the decisions of these men.

## COMMON EPIDEMICS AND THEIR PREVENTION.

**Influenza.** — The nature of this disease has been already discussed. A person sick with influenza expels the infecting organisms in minute droplets of mucus when sneezing, coughing, laughing, or shouting. The fingers of a patient are probably constantly infected. These minute droplets containing the infecting organisms are inhaled by others and infection may take place.

An ordinary infection will produce illness in from one to four days. The patient should be isolated and the case reported to the Board of Health.

The best known measures to avoid the spread of influenza are the following:

1. Prevent the crowding of people together in homes, schools, churches, theatres, cars, etc.
2. Provide plenty of ventilation.
3. Avoid extremes of temperature.
4. Provide ample nourishment and take recreative exercise out of doors.

**Measles.**—The cause of this disease is unknown. The incubation period is from five to ten days (average seven). A patient may "give" the disease to others, however, five days before he is aware that he has the disease. The most infective stage is when the patient is first "breaking out."

To prevent epidemics the following precautions should be observed:

1. All cases should be reported and isolated for five days after "breaking out."
2. Those exposed should refrain from contact with others for fifteen or eighteen days. Exceptions to this are those who have had measles earlier, as they are permanently immune.
3. Avoid contact with people by keeping away from crowds, particularly indoor gatherings.

Disinfection of rooms recently occupied by measles patients seems to be unnecessary. Middle-ear infection is the most common consequence of measles, while diphtheria and pneumonia following measles are often fatal.

**Cerebro-spinal meningitis.** — Epidemics of this disease occur in late winter and spring, and among children below five years, or young people between sixteen and twenty-four years of age. This disease is spread by discharges from the mouth and nose; and many carry the disease germs and infect others, without themselves being sick. Such people are called "carriers."

The incubation period is unknown. Protective measures are:

1. Isolation.
2. Extreme care to disinfect and destroy all materials expelled from the mouth and nose; these should be collected in gauze cloths and burned.

**Typhoid Fever.**—This disease is known to spread in no way except through the swallowing of bacteria from the excreta of a previous case. Sickness sets in from eight to fourteen days after infection.

Epidemics are prevented, or if under way, may be controlled in these ways:

1. Rigid examination of all foods and drinks, to insure purity and sterility.
2. Prohibition of sale of food and drink by peddlers.
3. Prevention of transmission by flies, by screening houses and destroying breeding places of flies.
4. "Carriers" should be identified, isolated, and "cured."
5. Careful sterilization of all dishes used by patient.
6. Insistence upon general use of typhoid serum.

**Mumps.**—The cause of this disease is unknown. Its manner of spreading is by the saliva which is often on fingers which have been purposely or thoughtlessly put into the mouth. Anything they touch is then infected, and passes on germs to any other person who may touch it.

The incubation period is from one to three weeks.

Epidemics of mumps are partially avoided at least by:

1. Isolating patients.
2. Guarding against infection of anything with saliva.
3. Avoiding infection droplets from a patient.

**Scarlet Fever.**—This disease is not as epidemic as many others and concerns chiefly young people. The cause is unknown; the incubation period is from one to seven days.

Transmission is through droplets or smears from the membranes of the mouth and air passages. "Carriers" are responsible for many cases. However, many epidemics are believed to have been caused by milk which had become infected during handling.

Its spread may be hindered or stopped by:

1. Avoiding crowding of people together.
2. Pasteurizing all milk supplies.
3. Isolation of patients.
4. Disinfection of all discharges from the mouth or nose.

Scales from the skin probably have no special infective power, and rooms once occupied by patients may be disinfected with formaldehyde if desired; this precaution is probably unnecessary.

If, after learning and perhaps experiencing some of the modern methods of health conservation, some are tempted to feel that such procedures interfere with personal liberties, they should remember that, in the long run, personal, family, neighborhood, school, and municipal health and hygiene are so closely interdependent that authority must be present at every point; also that observance of legislation looking toward the greatest common good should be accorded, not grudgingly, but eagerly and sympathetically by all.

## DEMONSTRATIONS OR LABORATORY EXERCISES

The following directions are made on the supposition that no teacher will be giving instruction in Physiology who has not had specific preparation for it, and will therefore be able to comprehend the significance of each suggestion, and know, in a general way at least, how to proceed with it.

A list of firms, from whom many materials called for can be obtained, is here given, as also formulæ for the making of necessary gases and reagents, and a table of equivalents between the English-American units of measure and those of the metric system. By anticipating the class or laboratory in a reasonable manner no difficulty will be found in making nearly every page of the text vivid and scientific in its presentation.

The chapter and page numbers refer to the relevant chapter and page in the body of the text.

### CHAPTER I

**Page 12.** — Numerous forms of protozoa can be easily obtained from dishes containing decaying pond plants, barely covered with water, which have been standing quietly a couple of weeks, and may be studied by placing them in a drop of water under a microscope.

**Page 15.** — Cells are easily shown by use of prepared slides. (See sources of material and apparatus, page 421.)

Fresh cells can be shown under a microscope as follows: in very thin cross sections of plant stem, *e.g.* corn stalk, lily; blood cells from frog, or in blood from finger prick; in thin bit of cartilage from upper end of femur bone of frog; in the thin tail of tadpole of frog, toad, or salamander.

**Page 17.** — Living protoplasm can be seen easily in live Amœbæ, generally found in dishes of decaying pond plants; in cells of pond weed Nitella, or Chara; or in hair cells from leaf of Tradescantia ("Wandering Jew"); high powers of microscope required.

**Page 23.** — Set aside (1) pond scum and weeds in dish with just enough water to cover, for 2 weeks; (2) hay in water (preferably in water in which other hay has been boiled, and then cooled).

Many unicellular animals will be found in a drop of this material under microscope. See also addresses of firms who sell this material.

## CHAPTER II

**Page 27.** — Show the class some charcoal, graphite ("lead" of a lead pencil), and some lampblack, calling attention to the fact that they are the same chemical element, carbon. Light a bit of candle and cover with a bell glass. The candle soon goes out. Explain that the carbon has combined with the oxygen in the air to form a new compound, $CO_2$ or carbon dioxid.

Show the class specimens of phosphorus, sodium, potassium, iron and sulfur. Place a little sulfur in an earthen dish and ignite it. It burns with a blue flame and gives off a suffocating gas. It has combined with the oxygen of the air, forming by *oxidation* a new compound, $SO_2$ or sulfur dioxid.

**Page 29.** — Tests should be made on a variety of common foods to prove the presence of proteid. White of egg, meat juice, ground oatmeal, show the test readily. With a solution of any one of them in water in a test tube (use 10 cc. or so) add a little strong nitric acid and heat to boiling; note the yellow color. Add ammonia, and note the orange color (Xanthoproteic reaction).

With rather weak solution of same material in test tube, add a little 1% sol. copper sulfate, then a little caustic potash; a violet color shows presence of proteid.

Try same reagents with starch and sugar solutions, and show that the tests are negative.

The gluten content of flour can be shown by putting a quantity of flour in a muslin bag and thoroughly kneading it in a pail of water. Much of the bulk will wash out into the water; the gluten will be left as a sticky, undissolved mass in the bag.

Pour a little hydrochloric acid into a small amount of milk. The curd which forms is largely casein.

Fibrin can be obtained from perfectly fresh blood by stirring it. The fibers which catch on the object used in stirring are fibrin.

Myosin can be shown in finely minced lean meat by soaking it in a little water for a few hours, and then pouring strong acid (nitric) into some of the juice. The material which coagulates is myosin.

**Page 31.** — (*a*) Shake up a little corn or potato starch with water in test tube and add a few drops of an iodine solution. A typical blue-color reaction will appear. Ground rice, flour, and cereal also respond readily. Use the same test on white of egg or sugar solution to prove validity of test.

(*b*) Put a few drops of 1% copper sulfate solution in test tube, and add solution of grape sugar (dextrose); then add a few drops of strong caustic potash solution and boil; a rust-red precipitate is formed in bottom of tube (cuprous hydrate or oxide).

If cane sugar is used, the above result will not follow unless the sugar solution is first treated with a few drops of 25% solution of sulfuric acid and then boiled; after this treatment, proceed as in case of dextrose and same result follows. Unmodified cane sugar does not contain dextrose.

Test starch or white of egg in the same way and show that the reaction is negative.

**Page 32.** — Put a small bit of fat meat (of size of pea is sufficient) in test tube and then pour in a little 1% solution of osmic acid. The fat turns black.

Place a few drops of olive oil in a test tube with a little water and shake vigorously. The oil forms a milky white emulsion. Examine a drop of milk with a microscope, and note the fat globules forming an emulsion. Put a small bit of fat meat on a *perfectly clean* slide, pour on a little ether and allow to evaporate; the ether dissolves the fat and on evaporation leaves a scum on the glass.

Tests of same sort with proteids or carbohydrates give negative results.

**Page 34.** — Boil tough, gristly pieces of meat and cut bones in a little water. A jelly will form as the solution cools, which illustrates the nature of gelatin.

## CHAPTER III

**Page 37.** — Since the character of the teeth is an indication of what an animal eats, it will be instructive to show different sorts of skulls with teeth in position; *e.g.* the human teeth indicate omnivorous diet; the rabbit teeth indicate herbivorous diet; the cat or dog teeth indicate carnivorous diet.

**Page 40.** — Boil an egg for ten minutes and remove the shell. Cut in halves to show the coagulated albumen and the yolk. Put some of the coagulated white in water and heat to prove that it will not dissolve. The white of raw egg coagulates in strong acid the same as in boiling water.

**Page 42.** — The proteid value of foods will be made more vivid if a considerable list of foods is on hand in quantities which can be used in connection with the table.

**Page 43.** — Cut a raw potato and place some iodine upon the cut surface. Treat a bean that has been soaked in water for a day in the same way. Which shows the more starch?

By definite trials, prove that egg albumen, meat, flour, and sugar do not react in uniform ways to this treatment. The test is specific for starch.

**Page 45.** — With a thermometer it will be easy to ascertain the melting point of some fats, *e.g.* butter, lard, pork fat, and mutton fat; then compare with temperature of the body.

**Page 54.** — With very sharp razor prepare very thin sections of raw and cooked potato; place under a microscope and demonstrate the points here mentioned.

**Page 55.** — Prepared slides of pork muscle infected with trichina are obtainable from nearly any dealer in microscopical preparations. Consult address list in another part of Appendix for partial list of dealers.

## CHAPTER IV

**Page 63.** — Fill a test tube half full of a solution of molasses (better than this is Pasteur's solution) and to it add a little yeast from an ordinary yeast cake. Let the mixture stand in a warm place for several hours. $CO_2$ gas, due to fermentation, will appear as bubbles. To prove the nature of this gas, take a larger amount of the fermenting mixture in a flask, and conduct the gas by a tube, as shown in Figure 26, into limewater; a white precipitate in the latter proves the presence of $CO_2$. After a time, the formation of alcohol in the sugar mixture can be detected by its odor.

To make this demonstration more vivid and complete, the fermenting solution should be put into flask, over opening of which a rubber tube is fitted, this in turn being connected to glass tube which can be led through a stream of water; then boil the liquid, and the vapor will be condensed in the cold glass tube and thus alcohol can be collected in liquid form. This carries out the principle of a still.

**Page 64.** — Mix starch and water in a small beaker. Heat, stirring constantly, and note how the mixture thickens owing to the bursting of the starch grains and the absorption of water.

Place a little of the mixture in a test tube and by the method used in the demonstration for page 31 determine that it contains no sugar. In another test tube mix a small portion of the starch solution with plenty of saliva. Be very sure that the test tube is perfectly clean; a trace of acid in it will prevent the desired result in this experiment. Place the saliva and starch mixture in a beaker of water. Heat the latter to about

the temperature of the body and let it stand for about ten minutes. Then test for sugar. A typical reaction should appear. The sweet taste of bread (a starchy food), after being in the mouth for a while is well known.

Examine saliva under a microscope to note the absence of any fermenting bodies, like yeast.

**Page 67.** — 1. To see yeast cells, examine a mixture of yeast and water with a microscope (high power).

2. Set aside, in a warm place, any food material such as piece of meat, in small receptacle; barely cover with water, and leave for two or three days. Then examine a drop, covered, under microscope with high powers, for numerous forms of bacteria. They have almost no color, and much care must be used in having just the right degree of illumination.

With a dull edged instrument (*e.g.* spoon handle) scrape a little material from inside lining of the cheek, or take a little material from between the teeth with tooth-pick; place this in a little water under cover-slip and examine as above. Bacteria will be numerous, perhaps loose epithelial cells also.

**Page 73.** — Fill four test tubes one-third full of water. Place in two of them a small bit of meat and in the other two a little white of egg. Plug all four with cotton. Place one of each set of two in a beaker of water and boil briskly for ten minutes. Set all four aside. Examine after two days and again after four days.

Many bacteria will appear in the unboiled tubes, with characteristic decomposition odors; the boiled tubes will show no deterioration.

## CHAPTER V

**Page 76.** — 1. A human skull should be at hand for direct reference to the teeth. Separate teeth to show roots, etc., can usually be obtained from a dentist. Other skulls containing teeth are useful to show different shapes in animals of different habits. Teeth of a rabbit or horse are very different from those of a carnivorous animal, *e.g.* cat or dog.

2. The layers of a tooth can be easily shown by use of prepared sections. See list of dealers in slides.

A model of a tooth can be rather easily cut from piece of hard soap.

**Page 77.** — Dip a bit of blue litmus paper into a little dilute hydrochloric acid, and note that it turns red. In the same way test vinegar, lemon juice, and sour milk. Dip a bit of red litmus paper into an alkaline liquid, like ammonia. Test soapsuds in the same way. Determine whether saliva is acid or alkaline.

**Page 78.** — To illustrate the action of an acid on the teeth, show the result of putting hydrochloric acid on an egg shell. Rapid corrosion follows.

**Page 79.** — The correctness of the text figure can be easily proved by use of prepared slides of taste buds. See list of dealers.

**Page 80.** — The connection between the nose and mouth cavities through the pharynx is easily shown by merely noting that any breath drawn in through the mouth can be expelled through the nose, or vice versa.

This point may also be illustrated by use of human skull, or if this is not at hand, by the skull of cat, dog, rabbit, etc.

**Page 81.** — The salivary glands of a cat show readily as soon as the skin is removed from the head, and in same location as in man. The duct from the parotid gland passes across the cheek region and no dissection is required to show most of its length.

**Page 84.** — Ciliary action can be easily shown under high powers of a compound microscope by mounting on a glass slide (in 0.6% salt solution) some ciliated cells scraped from roof of a frog's mouth, or a piece of a clam's gill. A correct idea of cilia cannot be obtained otherwise.

The surprising power of cilia to move objects is demonstrated by removing the lower jaw and floor of mouth complete from frog after brain has been destroyed. Keeping the surface of roof of mouth moist with normal saline solution (0.6%) place on it a small wooden block, size of pea. It will be moved along by the cilia.

**Page 84.** — 1. If one closes the nose passages by holding the nose between the fingers, and then swallows, the noise in the ears shows that a passage exists between them and the throat.

A model of the human pharynx should be used in this connection.

2. The several openings into the pharynx described in Chapter V can easily be shown in a recently chloroformed frog. The glottis is a longitudinal slit on a slight prominence at the back of the tongue. The gullet is immediately back of the glottis. The posterior openings of the nostrils are just back of the upper jaw, at the very front of the mouth. The Eustachian tubes can be seen as wide openings at the junction of upper and lower jaws; a bristle can easily be passed into them so as to demonstrate that the passage leads to the ear.

## CHAPTER VI

**Page 90.**—The body cavity, its divisions and contained organs, should be made plain by use of a manikin.

If some animal such as cat, rabbit, white rat, or the like can be dissected, the entire teaching of the body cavity and contained organs can be very easily made clear.

**Page 94.** — Coagulate some white of egg in boiling water in a beaker. Note that water alone will not dissolve such proteid. Put a piece of egg as large as the end of one's little finger (mincing it first) into a test tube half full of artificial gastric juice (see formula). Stand the test tube in a beaker of water kept at about body temperature (98°) and note that the egg slowly dissolves. When it has gone into solution, add copper sulfate and caustic potash; a rose-red color instead of violet shows that the proteid has been changed into peptone.

**Page 94.** — A solution of rennet can be obtained from any druggist, and its action on milk shown by merely adding a little to a tube of warm milk and allowing it to stand for about $\frac{1}{2}$ hour.

## CHAPTER VII

**Page 99.** — A very useful demonstration of the intestine with arteries and veins injected, and the whole made translucent, can be obtained from the W. H. Welsh Manufacturing Company, 1516 Orleans St., Chicago.

**Page 100.** — The teacher should demonstrate all the organs described in this chapter, as well as details like the mesentery, gall bladder, etc., by use of a manikin of the human body, or by the dissection of some small mammal. Even a fish shows much of interest in this connection, but has no diaphragm and is unlike the human in numerous ways.

**Page 101.** — The bile duct, gall bladder, and liver lobes are very easily dissected in the dog-fish.

**Page 103.** — Artificial pancreatic juice should be placed in a test tube with coagulated white of egg, kept at body temperature, and the test for peptones made. Starch should be treated in the same way, and after its digestion, tests made for sugar.

To show action of pancreatic secretion on fats it is best to imitate the conditions present in the intestine by mixing with the artificial pancreatic juice a little white of egg, as other things besides fat are always present. Pour into such a mixture some olive oil and shake vigorously. The emulsion thus formed will not separate as does a mixture of oil and water,

and a drop of it should be examined under a microscope and compared with milk.

## CHAPTER VIII

**Page 115.** — Cover the bulb end of a thistle tube with some membrane like the lining of an egg shell or a piece of goldbeater's skin, tying it tightly. Fill the bulb with solution of glucose, holding the bulb in dish of water while doing so to avoid breaking the membrane, which is very thin. Then lower bulb into the water till glucose and external water show the same level. Fasten the tube in this position; the water will pass into the glucose solution through the membrane, till glucose level is much the highest. This occurs against the force of gravity, under no compulsion except that of osmotic pressure.

**Page 120.** — The lacteal branches of the lymphatic system which arise in the walls of the intestine may be plainly shown in the mesentery of a cat or dog, if the animal is chloroformed about three hours after it has eaten freely of fatty meat and milk. On opening the abdomen immediately after death, the mesentery holding the intestine will be seen filled with numerous tiny ducts full of white, fatty emulsion.

## CHAPTER IX

**Page 123.** — The plasma and corpuscles in blood can be shown by putting a drop of fresh blood from a prick in the tip of the finger on a glass slide, with a little 0.6% solution of common salt. It is not possible to demonstrate the platelets except by special methods. Frog's blood is also easily obtained. For permanent mounts of the blood see address list of dealers.

**Page 125.** — 1. Defibrinated blood may be procured from a butcher, by catching blood directly from some animal and stirring it immediately, thus removing the fibrin as it forms. Blood so treated will not clot and will keep for some time. Put some in a large test tube, and by means of a glass tube opening into the bottom of the test tube run oxygen gas through the blood. The bubbles which will be thus formed will be of bright red color (oxyhæmoglobin). For methods of making this gas, see Appendix, "Formulæ and Methods."

2. The blood of a guinea pig, rat, or dog is best for showing oxyhæmoglobin crystals. It is not so readily shown in human blood. The amount of ether used should be only a fraction of that of the blood. If blood is merely mounted in water and allowed to stand some time, crystals form to some extent.

**Page 127.** — Prepared slides of blood are very useful here; see address list of dealers.

**Page 129.** — Arrangements may be made with a butcher to fill a pint glass container with fresh blood; this should be set aside immediately and left undisturbed until the blood has completely clotted. The less the specimen is disturbed before being shown in a classroom, the better. The serum will appear as a clear fluid about the clot; the latter will shrink, but will retain the shape of the container. Clean fibrin can be obtained by kneading a clot in water; the longer it is washed the better. It can then be preserved in 4% formalin, for use at any future time.

**Page 131.** — Dealers will furnish prepared slides of numerous sorts of bacteria, including the types here mentioned. They also furnish slides of blood showing the malarial organism, Plasmodium malariæ.

**Page 133.** — It will be worth while to procure and show "wrigglers" and pupæ of mosquitoes, as well as adults, or parts of them, under low power lenses. The young are easily obtainable, as a rule, from any woods pond in early spring. Prepared slides of mosquito mouth parts are purchasable.

## CHAPTER X

**Page 137.** — Obtain a turtle if possible, as it will show more satisfactorily than any other animal the external events of a heart-beat. Action continues a long time after the head is removed.

**Page 138.** — If time and opportunity permit, the teacher may show the heart of a beef or calf to the class, demonstrating the structure and action of this organ. Instructions should be given the butcher to leave the blood vessels connected with the heart *long*, *i. e.* the pulmonary artery and the aorta should be severed not less than five inches from their exit from the heart. The pericardium should be left on.

Before class period the specimen should be trimmed of all rough ends of tissues; the blood vessels should be nicely dissected out from the mass of tissue which surrounds them; in doing this the pericardium will be cut away in part, but should be left as perfect as possible. The external appearance of auricles and ventricles, the elasticity of the blood vessels, the contrast between arteries and veins, will be easily noted. If the following order of procedure is observed, practically every feature of anatomy and function of the internal parts can be readily shown.

Cut away the pericardium. Shut off the pulmonary artery with a strong clamp, as far from the heart as possible. Cut through the wall of the right ventricle toward the apex of the heart; carry this cut forward

*carefully* and remove most of the right ventricular wall, but do not get within an inch of the semilunar valves of the pulmonary artery. At this point the tricuspid valve, chordæ tendinæ, and papillary muscles of this side of the heart are fully exposed. If the conveniences of a water faucet and sink are at hand, slip over the faucet opening a rubber tube (about a yard long) in the end of which is a piece of glass tubing, both ends of which have been made smooth by heating. Insert the tube between the semilunar valves and fill the artery with water till it swells under the pressure; when very full, quickly draw out the tube; the semilunar valves will completely close and prevent the escape of water. If the specimen is held up to the light, the position of the valves and their perfect closure of the aperture can be clearly shown.

The action of the other type of heart valve can be shown as follows: First follow the aorta downward into the substance of the base of the heart, till the two coronary arteries are found; these must be tied off (with a broad cord, as the tissues are soft and easily cut by a small ligature) or the rest of the experiment will not succeed. Now cut off the top of the left auricle; the peculiar internal structure of an auricle is thus seen. Clamp off the aorta, as near its end as possible. Thrust the water tube down through the auriculo-ventricular opening, and fill with water. The left ventricle will first fill, and from there the water will go into the aorta and fill that. In the meantime, the two flaps of the mitral valve have risen and perfectly closed the entrance to the ventricle. When the internal pressure of the water has become considerable, draw out the tube, and the heart can then be manipulated to show better the valves in their closed position. After this, the ventricle can be cut open, the thickness of its walls compared with that of the right ventricle, the extreme thinness of the wall at the apex of the heart shown, and any other points which the instructor wishes to bring out.

Do not fail to cut out the semilunar valves and place in formalin for future use.

**Pages 143.** — To one end of a piece of thin rubber tubing about three feet long attach a syringe bulb by means of which water can be forced through the tube. Into the other end of the tube insert a glass cannula, drawn fine, in imitation of a capillary. As the bulb is pressed rhythmically a regular pulse can be felt in the tube by holding it between the thumb and finger. It can be shown a large class by connecting the short arm of a horizontal lever with the tube by means of an upright strip of wood, or other material; see figure on opposite page. The amount of "pulse" or change in diameter of the tube will be increased in proportion to the differences between the lengths of the arms of the lever.

**Page 145.** — Count the pulse rate; then run up stairs and down, or 50 yards and back, and make recount of the rate. Try effect of holding the breath.

**Page 147.** — A permanent preparation of a frog with arteries injected is purchasable, and very suggestive for the study given here. If laboratory work is given, fill arteries with starch mass (see formula), by injecting forward through the truncus arteriosus (big vessel leaving the heart), tying off both toward the heart before injecting, and beyond injection point after injecting. See addresses of firms selling injection syringes, etc.

**Page 148.** — Circulation may be shown as follows: Bore a hole one-half inch in diameter through one end of a piece of thin, softwood board. The cover of an ordinary chalk box will serve. Etherize a frog till wholly unconscious; wrap it in cheesecloth (to aid in handling) except one hind leg. Bind the frog to the board, letting the web of the free foot lie over the hole. Pin out the web so that it will be lightly stretched over the hole, and then place on stage of compound microscope, so that light will shine through the web. Capillaries of various sizes will be seen, with blood flowing in them.

**Page 149.** — These large blood vessels have probably been seen in the course of the demonstration for page 137, but can be further shown by use of a model of the heart.

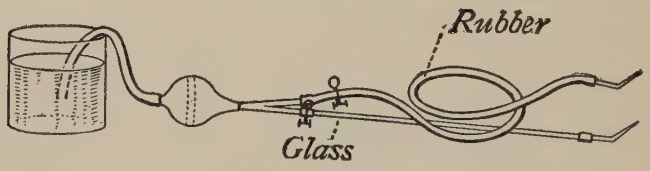
**Page 151.** — Prepared sections of arteries and veins should be shown under the microscope.

## CHAPTER XI

**Page 155.** — Arrange a rubber tube in horizontal position, with a capillary glass tube in one end and syringe bulb at the other. In the middle of the tube insert a glass T, and from this side branch let a glass tube lead vertically; its upper end should be open. On pumping in water with the syringe the pressure will be evident from the height to which water rises in the vertical branch. If the capillary at the end of the horizontal tube be removed, scarcely any pressure will be produced.

**Page 156.** — The conditions described here can be imitated by using the same apparatus as above, connecting a U-tube on the side branch, and filling it half full of mercury. The open end of the U-tube should be long enough so that subsequent rise of the mercury during the pressure on the syringe bulb will not throw the mercury out. All air must be taken out of the tubes between the water and mercury, as such an air cushion will practically counteract the effect of rhythmical pressure on the water. The capillary end must be used on the horizontal tube in this experiment.

**Page 157.** — Connect a syringe bulb with a Y-tube, and to the branches of the Y connect a glass and a rubber tube respectively; these should be of equal caliber and about four feet long; the rubber tubing should be thin and elastic. A removable glass capillary should be fitted to the free end of each tube. By having a clamp, or valve, in each tube near the arms of the Y, water can be sent through either tube separately. A continuous stream can be obtained when the bulb is pressed rhythmically, only when water is running through the rubber tube and then only when the capillary is attached to it. See figure below.




**Page 170.** — It will add to the interest of the class to show them thyroid tablets, adrenalin tablets, and powdered pancreatin such as is used medicinally and obtainable at any drug store, or from physicians.

**Page 172.** — The ready combination of oxygen with carbon in wood is strikingly shown by making oxygen and thrusting into it a glowing splinter. Fine wire taken from a piece of picture cord, loaded with a bit of flaming sulfur, will burn if plunged into a jar of oxygen.

## CHAPTER XII

**Page 178.** — If a large class is being taught, the trachea and lungs of a sheep or calf should be used to show the structure of those organs. In the case of a small class it is better to show these organs in position in a cat; the glottis, epiglottis and voice-box, as well as the arrangement of the lungs in the thoracic cavity, can be shown in such a small animal to advantage. The lungs should be inflated by inserting a tube into the trachea and blowing them full of air. The bronchi and bronchioles can be

dissected readily. A prepared section of an injected lung should be shown under the microscope.

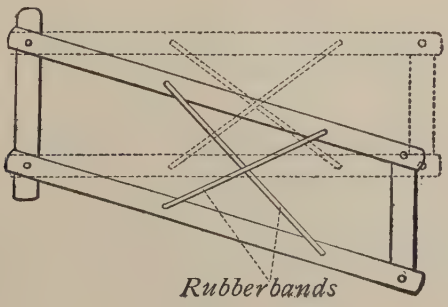
Page **179.** — The moving of particles of cork or bits of wood, etc., by cilia may be shown by pithing a frog, cutting away the lower jaw, and then, with the frog on its back, putting such particles on the roof of the mouth. If this be kept moist with 0.6% salt solution, these bits of material may be slowly but visibly moved backward to the opening of the gullet.

In pithing a frog the brain is destroyed, and thus consciousness of any pain, while the rest of the body is left entirely uninjured. Hold the frog in one hand, ventral side against the palm; put the first finger over top of head and hold against middle finger which, with the other two, grasps the body of the frog. With the back side of the blade of a scalpel placed transversely to the skull, find the groove between the skull itself and the first vertebra. Drive the point of the scalpel into this groove and sever the cord; then thrust a needle forward through the foramen magnum into the brain box and mix up the brain. In this condition the frog may give reflex movements, but these are from the cord alone. If it is desired to do away with these also, pass a long needle or stiff wire backward from the wound through the neural canal of the spine.

Page **183.** — Prepared slides of many forms of pathogenic (disease causing) bacteria can be obtained from dealers in same, and will greatly interest a class if shown under highest powers of the microscope.

## CHAPTER XIII

Page **191.** — Prepare the piece of apparatus shown in figure below. By the use of rubber bands as shown, demonstrate to the class how the internal and external intercostals raise and lower the ribs, and thus increase and decrease the size of the thorax.



**Page 193.** — Arrange a bell jar of the type shown in Figure 102; or let the long stem of a Y-tube pass through the cork and represent the trachea, the two short branches representing the bronchi. Attach to each "bronchus" a small rubber bulb, such as is on the mouth-piece affair used by small boys as a "squawker." Close the lower end of the bell jar with a sheet of rubber (obtainable from any dentist). By pushing the rubber "diaphragm" upward, its position when the breath is expelled is imitated, and the "lungs" collapse; when drawn down, air fills the "lungs." The leakages around the cork can be stopped by use of melted paraffin.

**Page 197.** — The capacity of the lungs, amounts of tidal air, complemental air, etc., can be effectually shown by use of thin wooden or pasteboard boxes of sizes to represent the different volumes referred to.

**Page 201.** — Show changes in air enumerated here as follows:

*a.* With air pump, syringe bulb, or bicycle pump, force the ordinary air of the room through a large test tube of limewater, by conducting the air through a tube to bottom of water so that the bubbles rise through it.

*b.* With a glass tube in the mouth blow through limewater. The calcium carbonate formed can be dissolved with a little hydrochloric acid.

*c.* Breathe on the thermometer bulb.

*d.* Moisture is left on clean, cold glass when it is breathed upon.

*e.* Exhale through a glass tube into strong sulfuric acid for some time; the acid turns black on account of organic matter in the breath. Extreme care should be taken not to draw the acid into the mouth.

**Page 205.** — That $CO_2$ is heavy and will not support combustion can be shown by leading that gas from a generator into the bottom of a pint fruit jar, for instance; it will drive out the air by collecting under it, thus showing its weight. A lighted splinter thrust into it will go out. If a piece of candle be placed in the bottom of a beaker and lighted, $CO_2$ can be poured into the beaker and the flame extinguished. See Appendix list of formulæ and methods.

**Page 206.** — To prove the fact of adjustment of breathing to different circumstances, have students count rate of breathing when quietly sitting, just after running up stairs and back, and before getting up in the morning. Averages struck from a large number of such reports will be interesting.

**Page 210.** — If possible, the larynx of a sheep, calf, or dog should be shown and dissected. This organ in a smaller animal is not large enough to be of any value. Models of this organ can be bought (see list of dealers in models) or one may be made from modeling wax, or carved from a

piece of hard soap. See list of dealers for source of modeling wax; such material is often used in grade schools or kindergartens.

**Page 214.** — Use can be made here of a tuning fork. If it is struck and the stem of it placed on the side of a hollow wooden box open at one end (or on a regular resonator), the combined effect of the vibration of the tuning fork and of the air chamber will be marked. The text suggestion of talking into different sizes of air containers should be carried out.

## CHAPTER XIV

**Page 219.** — The kidney of a sheep or pig is best adapted to show structure; that of calf or beef is not similarly constructed. Show the capsule about the kidney, and then split it open by cutting from the convex side toward the ureter. The cortex and medullary regions, pyramids, etc., are readily noted.

By use of a cat, or rabbit, the ureters, bladder, and urethra can be plainly demonstrated.

**Page 221.** — Prepared slides of injected kidney should be examined and Malpighian capsules containing glomeruli noted. The tubules will be seen in cross and longitudinal section, though none will be found complete.

## CHAPTER XV

**Page 228.** — Prepared slides of skin show practically all the points mentioned. A student should prove that a needle thrust into the epidermis causes no pain or bleeding.

The subcutaneous tissue holding the skin to the outer muscle layers of the body is easily demonstrable in any small animal, *e.g.* cat, rat, white mice, or any which may be obtainable.

**Page 235.** — Examine the skin with a simple magnifier and compare the markings of different fingers. Let one pupil be blindfolded and various parts of his skin tested with points of dividers. Scissors, firmly gripped, may very well be used in same way. Determine how near together they may be and yet be felt as two. Test the fingers, the back of the hand, the arm, the forehead, and back of the neck.

The determination of hot and cold spots requires too much apparatus for class use. However, interesting results are secured in the following manner: Have at hand two bowls, one containing quite warm water, the other cool water. Put finger of one hand into the warm water, a finger of other hand into the cool water. Is there a difference in sensations? After holding thus for a minute, place both in lukewarm water; what is the result? Try to explain why.

**Page 236.** — 1. If one holds the hand very near a piece of cold glass, *e.g.* the window glass, moisture collects on the latter. This is insensible perspiration.

When the opportunity presents itself, each student should very carefully weigh himself, follow this with very vigorous exercise during which perspiration is sensibly produced, and then weigh himself again. The amount of loss will be the amount perspired, most of which was sensible perspiration.

2. The arrangement of the dermal papillæ in rows, resulting in the fine parallel lines on the hand, with special patterns particularly well seen on the finger and thumb tips, is emphasized by use of a hand lens; the sweat glands open along the tops of these ridges. A class would be much interested in making a series of "finger prints," obtained simply by pressing the finger or thumb tip on to a paper or glass which has been smoked in gas or camphor flame.

**Page 242.** — Wet the finger and blow upon it gently. In spite of the fact that the breath is warm, it will feel cool. This is because the air current evaporates the water, and this uses up the heat of the finger.

## CHAPTER XVI

**Page 250.** — Throughout this study of the bones constant use should be made of a good human skeleton and of as many separate bones as can be procured. Interesting comparisons can be made with the skeletons of the fish, frog, and bird.

**Page 254.** — A disarticulated skull, like that shown in Figure 125, should be on hand for examination.

**Page 260.** — A fresh bone of some size, *e.g.* the humerus or femur of a sheep or calf, should be examined in class. Cross and longitudinal sections made with hand saw show essential structure. Dried bones do not show periosteum or marrow to advantage.

Rib bones of a sheep or pig show bone composition well. Either burn in fire to remove animal matter, or place in hydrochloric acid (15-20%) to remove mineral matter.

**Page 262.** — Microscopic sections of bone, cross and longitudinal, should be shown through medium powers of compound microscope.

**Page 264.** — Any fresh bone from a joint is good for showing cartilage. Microscopic sections can be conveniently made from fresh material (end of femur of frog, if none other is at hand) with hand razor; mount on slide in water or 1% acetic acid.

**Page 265.** — The leg of a sheep or pig, with muscles removed, is good for showing essential features of a joint. An articulated human skeleton should be referred to constantly in connection with discussion of various sorts of joints.

**Page 271.** — In discussing and illustrating the matter of shoes, reference may well be made to the Munson last, after which pattern all U. S. Army shoes are made. Aside from allowing plenty of room for the small toes, the inner side of the shoe should be so shaped that a line drawn lengthwise through the middle of the big toe and continued backward will pass through the middle of the heel. Plenty of space in front of the toes is also provided.

The endeavor to make the foot seem short and small by wearing high heels can be shown by the use of board drawings. The following line drawings are easily made:

Line A–B=apparent length of foot.
Line A–C=actual length of foot.

The lines should pass through the long, mid-axes of the big toes and the middle of the heels.

## CHAPTER XVII

**Page 276.** — Preparations of striped muscle make satisfactory material under high powers of the microscope. If fresh muscle can be separated into fine enough shreds, striæ show fairly well. Muscles of an insect, *e.g.* grasshopper, are especially good for this. If a section of tongue is available, it can be used in this connection; the muscle fibers running in different directions are strongly striped.

**Page 278.** — To show the relation of muscle to nerve, tetanus, etc., destroy the brain of a frog, remove the skin of the upper part of the hind leg, and by pulling apart the muscles locate the large sciatic nerve. By stimulating the nerve the muscles of the leg will contract. For more careful study proceed as follows: Follow the nerve carefully without stretching or even touching it any more than necessary through the hip joint to its exit from the spinal cord in the middle of the back; cut it there, carefully get it free from the surrounding tissues, and coil it up (two inches or so in length) on the muscle at the knee joint. Do not allow it to lie on the skin of the lower leg. Now remove the muscles from the thigh region, reserving the femur bone; cut the latter off near the hip, and clamp in a holder supported on a standard. Place the nerve on a pair of electrodes which are connected with a key and cells in an electric battery circuit, taking care all the time not to let the nerve get dry; moisten with 0.6% salt (NaCl) solution, with camel's hair brush. By opening and closing the key, a single or often repeated stimulus can be sent into the nerve, and the characteristic effect on the muscle noted.

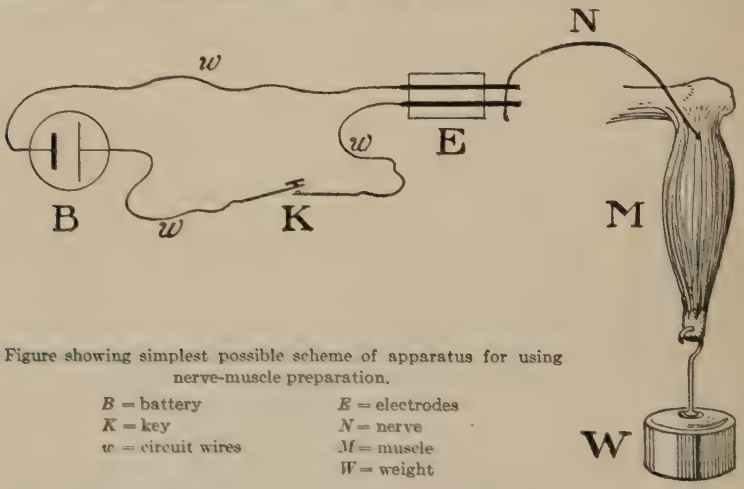



Figure showing simplest possible scheme of apparatus for using nerve-muscle preparation.

| | |
|---|---|
| *B* = battery | *E* = electrodes |
| *K* = key | *N* = nerve |
| *w* = circuit wires | *M* = muscle |
| | *W* = weight |

**Page 281.** — Microscopic preparations of smooth muscle which have been properly stained are most satisfactory for examination. Unless there is at hand special apparatus, it is not easy to show the normal reaction to stimuli of smooth muscle. So, too, its involuntary rhythmic contractions cannot be easily demonstrated unless, if taken from intestine of warm-blooded animal, it be maintained at the full body temperature in

specially devised chamber. It is not a practical experiment to attempt with limited time and apparatus.

**Page 282.** — To try out the point that heart muscle is apparently not susceptible of tetanus, lay bare the heart of a frog of which the brain is destroyed, and bend the electrodes of such an apparatus as is shown on opposite page so that the heart may be placed between them. Rapid making and breaking of the current can then be secured by use of the key.

## CHAPTER XVIII

**Page 290.** — The bones of the head of a cat are sufficiently thin so that they dissect easily. The brain coverings, fluids present, main divisions of the brain, and distribution of blood vessels can be admirably shown in such a dissection. If it is desired to show the distribution of gray and white matter, take such a brain (or preferably that of a sheep) and wrap it in cotton to prevent flattening against side of jar, and place for two weeks or so in potassium bichromate solution (see Formula 10). Sections can then be made through it with a razor and internal structures shown to any desired extent. The brain can be hardened immediately in formalin (5%), but will not show above differentiation.

While the brains of fishes have their parts developed to sizes which differ from those of the cat's brain, their general relations and order of arrangement are the same. The cartilage skull of the shore dogfish (Mustelus or Squalus) permits very easy and beautiful demonstration of all brain parts and nerves. See address list of dealers.

**Page 293.** — In order to demonstrate the so-called gray and white regions of the central nervous system, the parts must be prepared in specific ways. See formula for this purpose. Even free-hand sections of such material make clear demonstrations.

**Page 294.** — Prepared sections of the cortex of the brain show cells well, though the student will get but a limited idea of the brain as a whole from any one section which may be studied.

**Page 301.** — The general appearance and structure of the spinal cord can be well learned by obtaining at a market a piece of the spinal cord of some animal (*e.g.* the sheep or ox) still in its coverings. If this is hardened in equal parts of 5% formalin and 70% alcohol, it is easily handled. If the potassium bichromate method is followed the results will be better yet.

Prepared sections of the spinal cord will also be interesting.

**Page 302.** — That the cord is the path through which nerve impulses are sent out from the brain can be shown on the body of a freshly beheaded

frog. If electrodes are placed on the exposed anterior end of the cord, and a stimulus given from a battery current, or from an induction coil, the effect on the whole posterior part of the body will prove that the cord is the conductor of the shock. The above method is the neatest; but essentially the same result is obtained by probing the exposed cord with a needle.

**Page 305.** — Spinal nerves can be easily shown by removing the organs in the body cavity of a frog, after which the spinal nerves, including the brachial and lumbar plexuses, show without further dissection. Their number is less than in man, being ten only; it will also be easy to notice that two go to the arm (fore-foot) and are called the brachial plexus. Four pass to the hind leg, and together are called the sciatic plexus. The same terms are used in human anatomy.

**Page 307.** — The features of a nerve fiber as described here can be made out by separating a spinal nerve of a frog into its component fibers, and mounting them on a slide in salt solution under the microscope.

## CHAPTER XIX

**Page 314.** — Simple reflexes may be shown upon a frog whose head has been removed or whose brain is destroyed. The latter method is neater, while the former more evidently shows that the brain is absent. Suspend the frog so that its body hangs downward, and then gently pinch the toe or dip it into weak hydrochloric acid.

Touch a minute spot on the flank with strong acid and note that the hind leg will scratch it even with brain lacking. This well illustrates a spinal reflex.

**Page 324.** — The main components of the sympathetic system of nerves in a large frog show quite clearly as soon as the digestive tract and reproductive organs are carefully removed. Do not tear out the mesenteries or the sympathetic chain will probably be ruined. It is delicate but appears lying parallel to the back-bone, some of the way against it. The sympathetic system can be better shown in a cat if dissected by a person knowing the anatomy well.

## CHAPTER XXI

**Page 340.** — The parts of the eye mentioned in the next few paragraphs can be best shown in a model: the external muscles are generally shown on the head of a manikin.

Have pupils note how rapidly the muscles closing the eyes operate; only about .05 of a second is required to close the lid.

**Page 341.** — The muscles which move the eye can be well shown by use of the eye of a dog-fish. The skull is cartilaginous and easily cut away, and the muscles are diagrammatically plain. The nerves controlling them can also be identified if sufficient care is taken.

**Page 343.** — The eye of an ox can be easily dissected to show practically all the parts mentioned here. In taking off the choroid coat the pigment layer of the retina usually comes away also, but the cell layers will be left in position. Material should be perfectly fresh.

**Page 344.** — Let one student face a bright light while keeping one eye covered with the hand; others should notice difference in size of pupils when the hand is removed. This makes clear the function of the iris.

**Page 348.** — 1. A very convincing way of showing the image on the retina to be inverted is to mount the perfectly fresh eye of a chloroformed albino rabbit in one end of a stiff paper tube, the cornea looking outward. A person looking through the tube at the back of the eye sees the inverted image of whatever is in front of it. Always look at something brightly illuminated, *e.g.* anything out of doors on a sunny day, or an electric bulb, or candle flame.

2. A great many of the principles involved in the passage of light into the eye can be well shown by use of an artificial eye apparatus. The ordinary defects in the eye, as well as their correction, can also be shown with it. Ordinary loose lenses can also be used as shown in the diagrams; the source of the light should be confined in a dark box, with a single hole in its side, through which light rays can emerge and strike the lenses. A darkened room is imperative for all experimental work with light.

Permanent models of lenses and rays of light can easily be made. A lens of any shape, regular or deformed, can be made of modeling wax. This can be supported on brass rods above the middle of a board base. The source of light can be represented by a point on an upright piece of wood a foot or two from the lens, and the retina by a flat piece of board a foot or two from the other side of the lens. String or thread can be used as rays of light, and strung from source of light to lens, where they can be fastened with pins as the wax is soft. The exit of rays on the other side can be set up in a similar way, and their distribution on the retina shown by fastening the " rays " with tacks.

**Page 351.** — Adaptation of the eyes to different distances is easily felt by the pupil if he holds up a finger of one hand about a foot from his eyes, with finger of other hand in same line two feet away. Give attention first to one and then to the other. Board diagrams of what happens

in changing the angle of convergence of light entering the pupil will assist in making the facts clear.

**Page 353.** — If possible, arrange with some oculist, or physician with a knowledge of optics and of eye troubles, to bring into class pieces of testing apparatus and charts and to explain the commoner eye defects and method of correction.

**Page 355.** — Prepared sections of the retina will prove very fascinating if shown in this discussion, not for comment on its details, but in proof that it is a complicated, delicate structure.

**Page 358.** — Sets of differently colored worsted yarns can be obtained for testing for color-blindness. Require pupils to place together such samples as seem to be of the same color. It is quite probable that some student will show defective color vision.

## CHAPTER XXII

**Page 362.** — A large model of the entire ear must be on hand in order that the student may get a clear idea of it. A separate preparation of the temporal bone of the human skull, sawed open to show the ear structures, is also desirable.

**Page 366.** — In no other animal can the semicircular canals be so well shown as in the dog-fish, in which they occupy a large area just back of the eye and can be easily dissected out of the cartilaginous skull.

**Page 370.** — If stringed instruments are not at hand to show sympathetic vibration, two tuning forks, vibrating at the same rate, can be used. One should be struck and its stem placed upon a table top, while the other is held near it. Then smother the one struck and place the stem of the second on the table top. The second will be found to give out sound.

## APPENDIX

### Address List of a Few Firms Dealing in Materials for Demonstrations or Laboratory Work

*Zoölogical material, e.g. dog-fish, flies, mosquito adults or larvæ, etc.:*

(*a*) Supply Department, Marine Biological Laboratory, Woods Hole, Mass.

(*b*) The Chicago Biological Supply House, 5505 Kimbark Avenue, Chicago, Ill.

(*c*) The Southern Biological Supply Company, Natural History Building, New Orleans, La.

*Microscopic slides:*

(*a*) Powers and Powers, Sta. A, Lincoln, Neb.

(*b*) The Chicago Biological Supply House, 5505 Kimbark Avenue, Chicago, Ill.

(*c*) Ward's Natural Science Establishment, Rochester, N. Y.

(*d*) The Cambridge Botanical Supply Company, Waverley, Mass.

*Living unicellular animals:*

(*a*) Powers and Powers, Sta. A, Lincoln, Neb.

(*b*) The Chicago Biological Supply House, 5505 Kimbark Avenue, Chicago, Ill.

(*c*) Southern Biological Supply Company, Natural History Building, New Orleans, La.

(*d*) Cambridge Botanical Supply Company, Waverley, Mass.

*Microscopes and dissecting instruments:*

(*a*) The Spencer Lens Company, Buffalo, N. Y.

(*b*) Bausch and Lomb Optical Company, Rochester, N. Y.

(*c*) Central Scientific Company, 460 East Ohio St., Chicago, Ill.

(*d*) Arthur H. Thomas Company, Philadelphia, Pa.

*For physiological apparatus:*

(*a*) The Harvard Apparatus Company, Back Bay P. O., Boston, Mass.

(*b*) William Gaertner and Company, 5345 Lake Avenue, Chicago, Ill.

*For skeletons and models:*

(*a*) Ward's Natural Science Establishment, Rochester, N. Y.

(*b*) The Kny-Scheerer Company, 404 West 27th Street, New York City.

(*c*) Charles H. Ward, Rochester, N.Y.

*Modeling wax:*
(*a*) Any dealer in art goods.
(*b*) Devoe and Reynolds, Fulton Street, New York City.

*General laboratory supplies, not named above:*
(*a*) Arthur H. Thomas Company, Philadelphia, Pa.
(*b*) Central Scientific Company, Chicago, Ill.

## Formulæ and Methods of Making Various Substances Mentioned in This Book

1. Formula for iodine solution for use in testing for starch:

| | | |
|---|---|---|
| 4 | parts | potassium iodide |
| 1 | " | iodine |
| 40 | " | water |

Dissolve above and add 960 parts water. Smaller amounts may be made using same proportions.

2. Formula for Pasteur's solution:

| | | |
|---|---|---|
| 10 | parts | potassium phosphate |
| 1 | " | calcium phosphate |
| 1 | " | magnesium sulfate |
| 50 | " | ammonium tartrate |
| 750 | " | cane sugar |
| 4188 | " | water |

3. Formula for artificial gastric juice:

| | | |
|---|---|---|
| 0.2 | parts | hydrochloric acid |
| 0.1 | " | pepsin |
| 0.05 | " | calcium chloride |
| 0.05 | " | potassium phosphate |
| 100 | " | water |

The above is a precise formula, but for ordinary experiments for elementary classes the calcium and potassium compounds may be omitted and the other two used in greater strength.

4. Formula for artificial pancreatic juice:

| | | | |
|---|---|---|---|
| 0.6 | part | common salt | |
| 0.2 | " | sodium carbonate | |
| 0.2 | " | diastase | |
| 0.2 | part | pancreatin | |
| 0.2 | " | potassium phosphate | |
| 0.2 | " | lipase | |

100 parts water

For elementary work the potassium, diastase, and lipase may be omitted.

5. Formula for limewater:

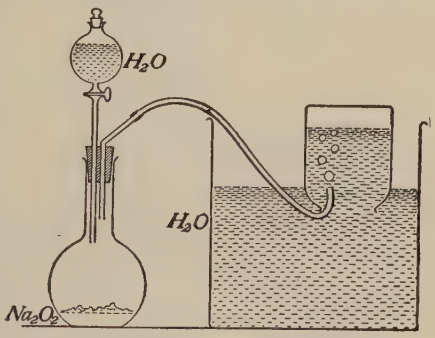
Add calcium hydrate to water till saturation is reached; then filter.

6. Formula for normal salt solution:

0.6–0.75%. This solution is merely sodium chloride in distilled water.

7. Fehling's solution for sugar tests:

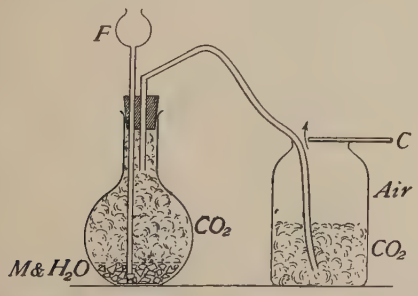
A quantity sufficient for convenient use can be made up as follows: Solution 1: dissolve 17 grams (about 1½ teaspoonfuls) of pure copper sulfate in 100 cc. (a quarter pint) of water. Solution 2: dissolve 75 grams (about 6 teaspoonfuls) of Rochelle salt and 25 grams (about 1½ 5-inch sticks) caustic soda in 250 cc. (about ½ pint) of water. Mix the two solutions thoroughly. This solution keeps in usable shape only for short time and it is more convenient to procure tablets ready for dissolving from a druggist. Whether the solution is correct or not can be ascertained by boiling a little; if it loses its color, the solution is useless.



Illustrating the method of making oxygen gas.

8. The following is a convenient method of making oxygen gas:

Put some sodium peroxid powder into a medium sized flask. This should be fitted with a rubber cork, through which runs a glass tube for leading off the gas, and a separatory funnel by means of which water can be slowly dropped on to the peroxid at will. The gas forms immediately and in large quantity. It can be most easily collected in jars over water by downward displacement; see figure.



Illustrating the method of making carbon dioxid gas.

9. To make carbon dioxid gas:

Put into a medium sized flask some broken bits of marble. Cover with water. Through the rubber cork in the neck pass a glass tube through which to lead off the gas; also a thistle tube, letting the lower end of the

latter reach below the water level. Pour hydrochloric acid into the thistle tube; $CO_2$ is immediately formed, though slowly, and can be collected by merely letting the gas run into the bottom of a jar; the weight of the gas will force out the air above it. Too free diffusion into the air should be prevented by covering the jar with a glass plate; see figure.

10. Formula for fluid in which to preserve parts of central nervous system so as to show white and gray regions:

10 parts potassium bichromate
15–20 " formaldehyde (40%)
500 " water

Let material stand in above mixture two weeks or so; if not hard then, place overnight in:

2 parts 5% formalin
1 " 95% alcohol (ethyl)

A fresh brain placed in the last named mixture alone will harden in two days; but the regions of gray and white matter will not be differentiated.

## Chemical Composition of Various Substances Mentioned in This Book

| | |
|---|---|
| Acetic Acid | $C_2H_4O_2$ |
| Alcohol | $C_2H_5OH$ |
| Ammonia | $NH_3$ |
| Caffein | $O_5H(CH_3)_3N_4O_2$ |
| Carbon Dioxid | $CO_2$ |
| Fat (stearin) | $C_{57}H_{110}O_6$ |
| Glycogen | $C_6H_{10}O_5$ |
| Glycerin | $C_3H_5(OH)_3$ |
| Hydrochloric Acid | HCl |
| Milk Sugar | $C_{12}H_{22}O_{11}$ |
| Proteid (egg albumin) | $C_{204}H_{322}O_{66}N_{52}S_2$ |
| Starch | $C_6H_{10}O_5$ |
| Sugar (grape sugar, glucose, etc.) | $C_6H_{12}O_6$ |
| Urea | $CO(NH_2)_2$ |
| Uric Acid | $C_5H_4O_3N_4$ |

## A Comparison of the Units of Measure Commonly Employed in America with Those of the Metric System

**Length**

1 meter (m.) = 1000 millimeters (mm.).
1 " = 100 centimeters (cm.) = 39.37 inches.
1 inch = 25.4 millimeters.
1 foot = 30.5 centimeters.
1 $\mu$ = $\frac{1}{1000}$ millimeter = $\frac{1}{25000}$ inch (nearly).

**Weight**

1 kilogram (kg.) = 1000 grams (g.) = 2.2 lb. Avoirdupois.
1 gram (g.) = 1000 milligrams (mg.) = 15.4 grains.
1 pound (Avoir.) = 453.6 grams, or about $\frac{1}{2}$ kilogram.
1 ounce " = 28.35 grams = 437.5 grains.

**Capacity**

1 liter (l.) = 1000 cubic centimeters (cc.) = 2.1 pints.
1 fluid ounce = 29.57 cubic centimeters.
1 pint = 16 fluid oz. = 473.1 cubic centimeters.
1 gallon = 3.78 liters.
1 cubic inch = 16.38 cubic centimeters.
1 cubic foot = 28.3 liters.

**Work**

1 kilogram-meter (kg.m.) = 7.23 foot-pounds.
1 foot-pound = .138 kilogram-meter.
1 foot-ton = 276 kilogram-meters.

**Heat**

1 unit of heat = heat necessary to raise 1 pound of water through 1° F.
1 calorie (Metric) = " " " " 1 gram " " 1° C.
Mechanical equivalent of heat unit = 778 foot-pounds.
" " " calorie = 427 gram-meters.

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